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Activities of the Gulf Coast Research Laboratory During Fiscal Year 1977-78: A Summary Report

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ACTIVITIES OF THE GULF COAST RESEARCH LABORATORY DURING FISCAL YEAR 1977–78: A SUMMARY REPORT

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ADMINISTRATION

During the year, the Gulf Coast Research Laboratory (GCRL) was the recipient of several significant gifts. These were the following: a 26-foot Lafitte skiff, powered by a 6-cylinder, 135-horsepower Palmer engine, valued at $7,000 and donated by Mr. Cyril R. Laan of Ocean Springs and New Orleans; 33 acres of Sioux Bayou marsh lands valued at $11,000 and donated by Tri-Land Development, Inc., Pascagoula; and a small wooden building valued at $10,000 from Keesler Air Force Base donated by the U.S. Department of Health, Education and Welfare. Additionally, two and one-half acres of property adjacent to the campus was purchased, including a small, wood-frame house.

The annual State appropriation for the general support of the Laboratory was $1,780,500. An additional $25,000 was received through a Special Library Improvement Allocation by the 1977 State Legislature and $672,468 was generated through sponsored research.

BOAT OPERATIONS

The boats that provide essential services include the 65-foot R/V GULF RESEARCHER, used in both the Laboratory's research and educational programs; the 38-foot steel trawler HERMES, used principally in the educational program; three diesel-powered cabin workboats; and some half-dozen Boston Whalers and other miscellaneous smaller boats operated on a part-time basis by scientists and technicians to meet the needs of Laboratory research projects.

During the year ended June 30, 1978, R/V GULF RESEARCHER was at sea for 61 days and 24 nights. HERMES spent 59 days at sea and the smaller boats made innumerable trips over the same period.

RESEARCH

ANADROMOUS FISHES SECTION, Dr. Thomas D. McIlwain, Head

Rearing and Stocking Striped Bass – Mississippi Gulf Coast (Funded by National Marine Fisheries Services [NMFS], U.S. Fish and Wildlife Service and GCRL): The second segment of the project dealing with the rearing and stocking of striped bass was begun in September 1977. The objectives of this program are to establish, by stocking, a striped bass population in Biloxi Bay; to stock sea-run striped bass and determine their success; and to establish a source of fry from Mississippi brood fish.

Approximately 582,000 striped bass of South Carolina origin were reared to a size of 2 inches and stocked into Biloxi Bay. Some 145,400 of these fish were reared from eggs taken from Mississippi brood fish. These brood fish were taken from Pearl River near Jackson, Mississippi, by Mississippi Game and Fish Commission (MGFC) personnel and transported to GCRL for spawning. Out of eight eligible females, four were tank spawned, three successfully. The successful spawn resulted in 1.7 million fry. One million were returned to MGFC for rearing and the remaining 700,000 were retained at GCRL for rearing.

No sea-run striped bass were stocked in this segment due to the unavailability of fry from sea-run stocks.

A total of 66 striped bass which were stocked in previous years were returned to project personnel. These fish ranged in weight from one-half pound to 19 pounds.

A sampling program is in progress to check for natural reproduction of previously stocked bass and for occurrence of juvenile striped bass, and to monitor previously stocked striped bass in order to continue assessing the results of all bass-stocking programs previously carried out in this area.

Bait Fish Rearing (Funded by Mississippi Marine Resources Council [MMRC]): A handbook was developed detailing the techniques for rearing bullminnows in closed systems and in ponds to supply the live-bait industry along the coast. The bullminnow is a favorite live-bait when available to coastal sport fishermen. Supplies are quickly depleted in late fall when the spotted seatrout (*Cynoscion nebulosus*) are running.

Sporting Analysis of St. Louis Bay (Funded by E. I. duPont de Nemours & Company, Inc. [Du Pont]): This program began in December 1977 and will continue for one year. The work entails gathering data on the total effort expended and total harvest of sport fish caught in St. Louis Bay. Data gathered will detail species composition, seasonal and numerical abundance, as well as size composition and method of capture and catch per unit of effort.

A Proposed Mississippi Marine Finfish (Selected) Fishery Management Plan (Funded by Mississippi-Alabama Sea Grant Program [M-ASGP]): As one of the five Gulf of Mexico states, Mississippi plays an integral role in the Gulf states fisheries. With a shoreline of only 70 miles, Mississippi ranks second in the total volume of seafood landed in these five states. Because of increasing national and international emphasis on fisheries and fishery management plans being developed, it has become more and more important for the

states to improve their management technique in this area. In essence, the states are the key to the regional and national success of our fisheries from all standpoints–biological, economic, social, environmental, administrative, etc. An improved finfish management system in Mississippi will not only improve the Mississippi output and conservation of the resource, but will contribute to improving both the Gulf regional fishery and the national fishery. A carefully developed and organized management plan for Mississippi does not exist at this time.

ANALYTICAL CHEMISTRY SECTION, Dr. Thomas F. Lytle, Head

Heavy Metals in St. Louis Bay (Funded by Du Pont): Because heavy metals pose a potential threat to estuarine water, whether coastal areas are developed industrially or residentially, an assessment of heavy metals is being conducted in St. Louis Bay where very little of either type development exists. Heavy metals are being examined in as many of the environmental components of the bay as possible. Because heavy metals may exist in the water column either in the soluble form or as particulate, both forms are being analyzed. The eventual repository for heavy metals is the sedimentary bed; sediments which will reflect a combined history of heavy metal input for as long a period as sampling will allow are good candidates for monitoring past exposure to heavy metals. Organisms may concentrate heavy metals either by absorption or ingestion from water or sediments. These concentrations may escalate to levels that are harmful to the organism, to its predator or man. The concentration of heavy metals in the tissues of organisms does not fluctuate quite so drastically as in the water nor remain as stable as in the sediments. However, because any grossly elevated levels of heavy metals would be of more immediate harm to organisms than to sediments, we need to know more about the heavy metal budget in the Bay.

A survey, to adequately describe heavy metals in bay waters, should include a constant monitoring of metals in many locations for a period of several years. This approach is presently not feasible even on a small scale; therefore, we must be satisfied to collect water samples that will give at least typical values for the Bay. Eight stations have been selected for heavy metal collections from among 11 stations used for nutrient studies. These stations are being occupied once every second month for the purpose of making a collection sufficiently large to measure the following 17 metals: copper, chromium, cobalt, nickel, zinc, cadmium, iron, titanium, vanadium, mercury, arsenic, selenium, antimony, strontium, molybdenum, beryllium, and lead, plus cyanide. The sampling does not coincide with any other sampling effort in order to avoid any contamination from the research boats in the Bay. The samples have been filtered, preserved and frozen, then transported to the Laboratory for analysis. Sediments from these eight stations and six more have also been collected. An assortment of resident species of fish and invertebrates are being collected for dissection and analysis. Marsh soils and plants will also be analyzed.

Of prime concern has been the construction of a "clean" laboratory for trace metal analysis. All metallic objects were removed if feasible, and if not, coated with epoxy. Separated from the hall by an outer office, the clean area was sealed with epoxy paints and other plastic sealants and is supplied with constant, positive-pressure, ultrafiltered air. A Teflon-clean bench-hood for critical sample treatments and a fused-quartz still for final water distillations were installed. Ceiling tiles were replaced with plastic panels cemented in place. Since debris from corroded surfaces or dust from any source could seriously compromise trace metal results, all efforts are being made to prevent these from occurring in the laboratory.

When analyses are complete, the present load of heavy metals in St. Louis Bay should be known with a fair degree of certainty.

Nutrients in St. Louis Bay (Funded by Du Pont): A program was designed to determine the levels and distribution of nutrients in St. Louis Bay. Later it was decided that the term nutrients was misleading; therefore, the measurements are now referred to as water quality parameters (WQP). Envisioned originally as measurements to support other studies in the Bay, this concept was soon abandoned because of the difficulties of coordinating all possible interests with the WQP samples. Because it appeared that productivity measurements would suffer most from lack of synopticity with that collection, samples for WQP were collected in a manner to achieve results that might be directly correlated. The parameters chosen were: orthophosphate, total phosphorus, nitrate, nitrite, ammonia, chloride, sulfate, suspended solids, turbidity, alkalinity and silica. In addition, samples were also collected for total inorganic and organic carbon and distributed to the Environmental Chemistry Section.

The methods used for analysis were those in the *Federal Register*, December 1976. Though these methods have proved defective in some respects, matrix modifications in samples and standards have almost without exception proven them to be reliable. The only measurement remaining an enigma is that of total phosphorus. Water samples are collected once monthly in a manner to preserve the integrity of the samples for all WQP. Initially, samples for all parameters were collected and preserved individually. However, this procedure proved very time-consuming and inept. Therefore, to collect samples as quickly as possible (to remove the time factor in station comparisons), one sample bottle is now used for all parameters. These samples, preserved on ice, are rushed back to the Water Analysis Laboratory for processing. This sampling procedure has worked better than a field-based procedure.

Eleven stations are sampled in this study including some in the Bay proper, others near residential areas, in large bayous and both the Jourdan and Wolfe rivers. Surface samples are collected at all stations each month; in addition, at half of the stations, vertical profiles of water quality parameters

are made when depths permit. Correlations of the various parameters are being made; nutrient budgets are being established and overall water quality evaluated in St. Louis Bay.

Techniques Development for Oil Pollution Assessment (Funded by GCRL and the Bureau of Land Management): This is a continued study designed to find the best procedures both to chemically analyze geological and biological samples and to assess the proper parameters by which to designate whether or not the samples are polluted with petroleum hydrocarbons. Sediment samples, taken before emplacement, during drilling and after drilling, were collected from 25 strategic locations at a Texas oil rig site chosen by the Bureau of Land Management. These unique sampling and analyses offered enough hydrocarbon data to apply various computer programming techniques to ascertain the most effective parameters in assessing oil pollution.

BOTANY SECTION, Dr. Lionel N. Eleuterius, Head

Salt Marsh Vegetation of Davis Bay (Funded by GCRL): Quantitative information is being accumulated on the relationship of marsh acreage versus open water in this productive estuarine system. In addition, the total area drained by the marsh and the amount of rainfall will be determined in order to study an entire estuarine ecosystem from the plant ecology viewpoint. A detailed vegetative map is being prepared as well as a map of the standing crop of all marshes surrounding Davis Bay. This information is basic to further detailed botanical and ecological studies in the area around GCRL and should provide information for students, scientists and others within the State.

Populational Studies on Salt Marsh Species (Funded by GCRL): This ongoing research is presently concentrated on the salt marsh rush, *Juncus roemerianus.* Considerable population information has been gathered on the species and a portion of it is now in manuscript form. The ultimate goal is to document the distribution and the vegetative growth pattern of the major salt marsh species inhabiting the tidal marshes in Mississippi. Such populational studies are of considerable importance in relation to ecological work since ecotypes (single sexes) may dominate or compose large tracts of tidal marsh. Similar work has been initiated on *Scirpus olneyi* and *Distichlis spicata.*

Ecological Studies on Seagrasses and Salt Marsh Species (Funded by GCRL): Ecological studies on salt marsh species will entail synecological studies where more than one species compose the vegetation. Included in this study is consideration of the hydraulic aspects of flooding of various salt marsh zones to be done in cooperation with the Physical Oceanography Section. Grand Bayou, a high-salinity marsh dominated by *Juncus romerianus* on Deer Island, Mississippi, has been tentatively selected for this portion of the study.

Studies of other ecological aspects of this tidal marsh have been initiated. Tidal inundation and discharge rates can be easily established because of the small, contained ecosystem represented in Grand Bayou. Quantitative data on plant productivity and the nutritive discharge of detritus and other water quality parameters will be assessed on the discharge and on the rising tide.

Autecological Studies on Vascular Plants of Mississippi Salt Marshes (Funded by GCRL): This project is essentially an extension of population studies in that ecological parameters such as soil nutrients, soil-water salinity, elevation, other chemical and physical aspects of the habitats (i.e., soil texture, evaporation), and the life history of the plants will be considered.

Progeny and Genetic Studies on the Salt Marsh Rush, Juncus roemerianus (Funded by GCRL): This work is ongoing research that has been carried out over a number of years. Plants have been grown for several years from seed to obtain Mendelian ratios establishing the genetic mechanism responsible for the sexual distribution found in this rush species. The work constitutes an effort to obtain basic information on this species which dominates Mississippi marshes. During the past year, controlled crosses between known-parental types have been achieved and their seeds are presently being germinated. Hopefully, they will produce mature plants in less than the 2 years required under field conditions.

An apparatus has been constructed in the greenhouse that will extend or shorten the day to induce flowering. Also, experiments have been conducted dealing with the physiological requirement of a cold period, known as vernalization, to induce flowering in this rush. If flowering can be induced, the growth and flowering cycle can be accelerated.

An Illustrated Guide and Key to Salt Marsh Plants (Funded by M-ASGP and GCRL): The purpose of this work is to prepare an illustrated guide and key to the salt marsh plants of Mississippi. It entails about 180 line drawings and scientific descriptions of local species of vascular plants. Keys to families, genera and species are being prepared.

A Phytosociological Study of Horn and Petit Bois Islands (Funded by National Park Service, U.S. Department of Interior): During the first year of this two-year study, a large number of exclosures were established to assess the effect of animals such as nutria, hogs, and rabbits on the vegetation. Concurrently, phytosociological sampling was initiated to obtain information on community composition and successional patterns and interrelationships between the plant communities on these islands. Major products resulting from the work will be maps of large format that will accommodate many detailed vegetational features of Petit Bois and Horn islands. Hopefully, these will be prepared in color. Such color preparations will be of considerable value in the proper management of the islands and invaluable as baseline data for future scientific studies. Considerable effort has been made to obtain information on insular marshes which will be part of general ecological studies on salt marshes in Mississippi. A detailed report, pointing out the special features of these islands, is in preparation.

St. Louis Bay – Botanical Survey and Plant Ecology of Salt Marshes and Submerged Meadows (Funded by Du Pont): Vegetational and community-composition mapping of salt marshes and submerged grass beds as documentation of standing crop, annual production and chemical characterization of indicator plants and associated soils is in progress as part of a baseline environmental study. Continuous recordings of soil-water salinity (isohalines) are being obtained by *in situ* soil-water salinity sensors. Concurrent continuous recordings of light energy from underwater and aerial sensors are also being obtained.

ECOLOGY SECTION, Dr. Robert A. Woodmansee, Head

Phytoplankton Productivity in St. Louis Bay (Funded by Du Pont): Phytoplankton productivity is a fundamental community process of primary significance to the aquatic food chain. It is sensitive to a variety of unnatural environmental perturbations and is affected by a number of naturally occurring variables. Phytoplankton productivity is being measured at six locations in St. Louis Bay by both dissolved oxygen and radioactive carbon techniques and is being related to light intensity, temperature, nutrients, chlorophyll, phytoplankton and grazing pressure.

Environmental Baseline Survey of St. Louis Bay: Benthic Study (Funded by Du Pont): Monthly sampling of benthic infauna and epifauna was initiated in December 1977 as part of an overall effort by the Laboratory to conduct an environmental baseline study in St. Louis Bay. Prior to sampling, equipment was purchased and modified as needed. It was also necessary to hire and train two additional technicians. Beginning in December, 39 infauna and 14 epifauna samples were collected each month and transported to the Laboratory for processing.

Seasonal and Spatial Changes in the Macrobenthos of Simmons Bayou, Mississippi (Funded by GCRL): A benthic study conducted in Simmons Bayou was concluded during this reporting period. From this study, a paper entitled "First Gulf of Mexico Coast Record of *Manayunkia speciosa*" by Walter T. Brehm, was accepted by *Northeast Gulf Science* for publication. Another paper entitled "Seasonal and Spatial Changes in the Macrobenthos of Simmons Bayou, Mississippi," was prepared for presentation at the October meeting of the Gulf Estuarine Research Society.

A Study of the General Plankton and Floating Components of the Water Column from the Surface to 1,200 Meters at Two OTEC Sites in the Northern Gulf of Mexico (Funded by Department of Energy, Ocean Thermal Energy Conversion [OTEC] Program, Lawrence Berkeley Laboratory): Bimonthly cruises aboard the NOAA boat, VIRGINIA KEY, to OTEC sites for the purpose of collecting plankton and general hydrographic data were initiated in June 1978. A sampling program was established to determine the quantity and position within the water column of planktonic species. This project should provide the OTEC Program with some of the necessary biological data for proper design and implementation of an offshore thermal energy conversion plant.

ENVIRONMENTAL CHEMISTRY SECTION, Dr. Julia S. Lytle, Head

Sediment High Molecular Weight Hydrocarbons in Bay St. Louis (Funded by Du Pont): During the past decade there has been an increasing concern over the possible effects of petroleum hydrocarbons in the marine environment. Because of this concern, a great amount of research on the biogeochemisty of these compounds is in progress. National agencies are initiating hydrocarbon baseline studies to be made on areas of potential oil pollution which would be subject to economical and environmental stress. With the building of a large Du Pont plant on the shore of the Bay, hydrocarbon baseline information was essential. To document the present levels of hydrocarbons (aliphatic and aromatic) in St. Louis Bay, 13 sampling stations were used in assessing the hydrocarbon levels from the rivers and from known sites of possible hydrocarbon inputs and also correlated with other sediment studies made at these same stations. Sediments were collected during the first month of the study and hydrocarbon analyses made. These same stations will be sampled during September, nine months after the first collection, and again analyzed.

In an effort to use hydrocarbon data to detect the presence of petroleum pollution, parameters have been derived from gas chromatographic data that indicate the presence of petroleum hydrocarbons. Thirteen of these parameters were measured in all sediments analyzed. Changes can be detected by measuring the same parameters at any later time, thereby establishing both qualitatively and quantitatively the addition of petroleum influx to these sediments.

Studies of Chemical Constituents of Primitive Plants (Funded by GCRL): Chemotaxonomic and geochemical studies continued on primitive plants. Similar studies have been completed previously on ferns, mosses, fungi and lichens. The present study has been extended to include lilies, rushes, sedges and grasses. This study has two purposes. One purpose is to investigate the distribution of biosynthetically related compounds, hydrocarbons and fatty acids, to relate them to a series of ancient plants and to determine what chemical changes took place in the evolution of plants. The other purpose is to establish hydrocarbon and fatty acid distribution patterns that can help in identifying natural-source materials and their environments, and distinguishing them from pollutant sources.

The Fate of Organic Pollutants in Estuaries and Rivers Emptying into the Mississippi Sound (Funded by GCRL and Du Pont): This study is a cooperative effort with the Analytical Chemistry Section. The organic pollutants are isolated and characterized by the Environmental Chemistry Section, and trace metals and nutrients are examined by the Analytical Chemistry Section. The object of the study thus far has been to document the hydrocarbon and total organic carbon levels in St. Louis Bay, Biloxi River and Bay, and the Pascagoula River Systems.

In view of the ever-expanding development of coastal zones, a continuing pollution assessment study is proposed to deal with the following issues of environmental concern:

1. The present condition of Mississippi Sound and adjacent bays and rivers needs careful documentation. Following this, future monitoring efforts can then be determined.
2. The sources of pollutants should be located and dispersal of these pollutants documented. The mechanism responsible for transport and deposition of pollutants in any area of the Sound must be known for various environmental conditions. Fate predictions of materials discharged into the Sound system may then be possible.
3. The public needs to be made aware of present and future dangers of pollution to water resources of the State. Only an informed public can take action to prevent future detriment to the environment and insist upon clean-up procedures.
4. Guidelines for proper development of the coastal zone should be facilitated by a thorough knowledge of impact potential of pollutants at any location in Mississippi Sound.

There will be two distinctly related areas of research. Trace metals to include such elements as copper, cadmium, zinc, nickel, manganese, silver, cobalt, lead and iron will be examined in all sample types used in the study. Their known toxic nature, stability and numerous sources warrant attention in any study. Hopefully, the data gained here will also be useful in predicting the fate of radionuclides as well. Among the organic pollutants to be studied will be hydrocarbons that can result from petroleum pollution. Fatty acids and alcohols, not occurring extensively in petroleum, may be used as tracers of natural organics in the Sound as well as providing additional information on the composition of organic constituents of sediments and water.

Both water samples (surface and bottom) and surface sediments will be collected routinely at each sample site. Since trace metals and organics both are generally associated with fine-grain materials when in a nondissolved state, suspended material will be examined separately from dissolved components and grain-size analysis of sediments conducted. This may provide correlations to clarify sources of deposited pollutants and assess the importance of suspended materials in transporting pollutants. Other studies have indicated the importance of trace metal-organic associations in water and sediments; therefore, this relationship will be examined as closely as possible. Where more appropriate, laboratory conditions will replace natural ones in trying to elucidate the character of this relationship.

Accumulation of Petroleum Hydrocarbons in Clams Taken Near Dredging Operations (Funded by U.S. Corps of Engineers, subcontracted from Micro-Methods, Pascagoula, Mississippi): In order to assess the damage of petroleum hydrocarbons on clams, a study was made to determine the extent of accumulation of petroleum hydrocarbons in clams from two areas, one area off the Florida west coast and the other near Puerto Rico. In doing so, clams from "clean waters" defined the background hydrocarbon distributions while clams from dredging areas defined the input due to mobilization of hydrocarbons from the deposited dredge spoil. Sixty-four samples of clam tissue were analyzed for both aliphatic and aromatic hydrocarbons. Total hydrocarbons in clams were extremely low (less than 1 part per million). Various gas chromatographic parameters were used to help distinguish between biogenic hydrocarbons and those of petroleum origin.

It was apparent that clams taken from various locations accumulated different types of hydrocarbon pollutants according to types of pollutants in the dredging muds. Information concerning sediments and their hydrocarbon distributions is essential to the understanding of the uptake and resuspension of hydrocarbons. We were not given access to this information, thus complete interpretation could not be made.

FISHERIES MANAGEMENT SECTION, Mr. William J. Demoran, Head

Oyster Resource Assessment and Monitoring Segment of the St. Louis Bay Baseline Survey (Funded by Du Pont): The study involves the mapping of existing oyster reefs to determine their present condition as to productivity, natural mortality, spawning and setting, and predators with emphasis on the incidence of one known disease that affects oysters along the Gulf coast. Historical and recent salinity data are being analyzed in order to determine what effect they have had and are having on oyster growth in the Bay.

An Economic, Environmental, Engineering and Legal Assessment of Oyster Depuration in Mississippi (Funded by M-ASGP): This study deals with the managerial aspects of the oyster resource as they might pertain to harvesting and monitoring of oysters as they are processed in the depuration plant.

FISHERIES RESEARCH AND DEVELOPMENT SECTION, Mr. J. Y. Christmas, Head

Fishery Resources Monitoring and Assessment (Funded by NMFS and GCRL): The completion report and manuscript for the original monitoring and assessment project (culminated in September 1976) were finalized and approved by NMFS. The manuscript includes papers covering the principal species in each fishery. The following were considered for each species: immigration; growth; size distribution and abundance collected by various gear types; distribution by habitat, estuarine area, temperature and salinity; seasonal trends in abundance; prediction of abundance; length-weight relationship and condition; and age at maturity.

The current monitoring and assessment project is on schedule. Cooperative efforts to provide data leading to achievement of optimum yield from fishery resources are continuing. Appropriate segments of this work have been closely coordinated with NMFS research in Gulf waters.

Continuing liaison with the Mississippi Marine Conservation Commission (MMCC), M-ASGP, numerous other State and Federal agenices and industry representatives has provided for a progressively improved scientific base for fishery management.

The Mississippi brown shrimp crop for 1978 was adversely influenced by the occurrence of a high-salinity, low-temperature and low-dissolved oxygen watermass that moved through the island passes just before the MMCC opened the Mississippi shrimp season. It was opened in accordance with recommendations based on project data collected for them by GCRL. Catch data were not available but preliminary estimates indicated a good average year for brown shrimp with improved catches expected in July based on the abundance of postlarvae on the nursery grounds.

White shrimp followed typical patterns of abundance with a good crop predicted for late summer and fall harvest. Postlarvae and early juveniles appearing in estuarine nursery areas and available catch data for pink shrimp indicated increasing harvests from Mississippi waters.

Blue crabs were abundant throughout this period and a very large year-class of juveniles were in the sampling area during the 1978 sampling period, indicating that the blue crab population can continue to provide as many hard-shell crabs as processors can handle. However, changes in harvesting regulations may adversely affect production from Mississippi waters.

While total 1977 Gulf menhaden landings were appreciably below those of 1976, landings in Mississippi increased 27% from 1976. Fishing effort in the Gulf purse-seine fishery in 1977 was 8% less than in 1976. Predictions based on juvenile abundance and a 6% increase in effort indicated a good season in 1978. Preliminary catch data indicate that predicted harvest volume will be accomplished.

As expected from the abundant year-classes reported last year, spotted seatrout and redfish provided excellent fishing in Mississippi waters in 1978. After a decrease in numbers caught from the 1976–77 year-class of croakers there was a sharp increase in the 1977–78 year-class moving inshore. Survival of croakers to recruitment in the offshore fishable population continued to be low. Other finfish species followed typical patterns of movement with no evidence of serious problems.

Fisheries Planning (Funded by GCRL): Active participation in fishery planning activities of NMFS, Gulf States Marine Fisheries Commission, the Commission's Technical Coordinating Committee and subcommittees, Gulf State-Federal Fisheries Management Board, Sea Grant Association, MMRC, MMCC, Gulf of Mexico Fisheries Management Council and several professional societies provided for effective input of Mississippi's position in practically all Gulf of Mexico fishery planning activities. Project personnel served as a member of the MMCC.

A regional management plan for Gulf menhaden, completed and published by GCRL last year, was implemented by the Gulf State-Federal Fisheries Management Board. Laboratory personnel served on the menhaden management committee. Scientific and statistical committees for plans being developed by the Gulf of Mexico Fisheries Management Council included several members of the GCRL staff who have acquired expertise in specific fisheries.

Development of a Regional Fishery Management Plan for Gulf Shrimp (Funded by NMFS): *The Shrimp Fishery of the Gulf of Mexico United States: A Regional Management Plan* was completed and published in August 1977. The 128-page document was developed in a series of 11 workshops. The Gulf Shrimp Management Task Force included specialists from each of the five Gulf states and open-meeting workshops were held in each state to facilitate fisherman and industry participation in the planning process. A comprehensive summary of this plan (20 pp) was developed and published in November 1977. The plan was implemented by the Gulf State-Federal Fisheries Management Board early in 1978. Laboratory personnel served on the Board's Shrimp Management Committee.

A Proposed Mississippi Marine Finfish (Selected) Fishery Management Plan (Funded by M-ASGP): This project provides for development of a proposed management plan for selected Mississippi marine finfish in a cooperative effort with the University of Southern Mississippi. A working group comprised of personnel from GCRL, USM, MMCC and Sea Grant Advisory Service, held workshop sessions each month. The MMCC selected ten species for inclusion in the plan and appointed a 12-person Advisory Committee to provide input from recreational and commercial fishermen, processors and consumers. Work is proceeding on schedule.

Environmental Baseline Survey of Bay St. Louis, Nektonic Macrofauna (Funded by Du Pont): This segment of the multidisciplinary study of St. Louis Bay provides for collection and study of the nektonic macrofauna in the Bay. Sampling was started in October 1977 and by the end of June 1978, a total of 252 biological samples and 1,080 physico-chemical measurements had been completed. All samples were processed on schedule and verified data were stored in the Laboratory computer files. About 200 species have been identified from biological samples.

GEOLOGY SECTION, Dr. Ervin G. Otvos, Head

Offshore Barrier Island Study (Funded by GCRL): This is a study of the geologic history, genetic conditions and present state of six Mississippi-Alabama barrier islands. Drilling on western Petit Bois Island was completed in the summer of 1977. Two coreholes drilled in 1978 on western Dauphin Island completed that island's subsurface geological exploration. Five coreholes were drilled in a transect between the mainland and Horn Island. The U.S. Coast Guard and the Mississippi National Guard provided periodic photo coverage of certain critical island sections, allowing the monitoring of changes over a short period of time. Processing of previously acquired core material progressed

in the sedimentation laboratory. Part of the accumulated findings on this island have been organized for a later presentation at a professional meeting as well as for publication.

Santa Rosa Island (Funded by GCRL): Study of this island has started with the acquisition of U.S. Corps of Engineers' drill core material from Birmingham, Alabama, and island drill core material from a testing laboratory in Pensacola, Florida. Comparison between this island and the Alabama-Mississippi barrier islands has major significance in understanding their formation and development conditions.

Origins of Lake Pontchartrain and Surrounding Holocene Areas (Funded by GCRL): Collection and organization of available material continued with the view of publishing in the fall of 1978.

Holocene Geology of Hancock County Marshland (Funded by GCRL): A paper was prepared in conjunction with the Botany Section, based on available data involving floristic aspects of the study area.

Chenier Genesis in the U.S. and Worldwide (Funded by GCRL): A paper has been prepared with the collaboration of Dr. W. A. Price, Corpus Christi, Texas, and accepted for publication in *Marine Geology*.

Beach Sand Analysis (Funded by GCRL): Granulometric analysis was performed on numerous samples for the Physical Oceanography Section.

Shoreline Erosion–Mitigation Assessment and Planning for the Mississippi Gulf Coast (Funded by MMRC): This project was performed jointly with the Physical Oceanography Section. A report on partial results was submitted, but the second stage was not funded.

Pleistocene Development in Southeastern Louisiana (Funded by GCRL): Field and laboratory work continued. Special attention was paid to the Bayou Sara area's (Mississippi-Louisiana) Pleistocene chronological problems.

St. Louis Bay (Funded by Du Pont): Monthly sediment analyses of collected Bay samples were performed on this project.

MICROBIOLOGY SECTION, Dr. David W. Cook, Head

Evaluation of Methods for Long-Term Freezer Storage of Blue Crabs for Use in Picking Plants (Funded by MMRC): An evaluation was made of two procedures for freezing and storing blue crabs until they could be picked. In one procedure, the crabs were given a short cook and then frozen whole with a final cook before picking. In the second process, the crabs were cooked and packed with only the crab cores being frozen. Included in the evaluation were pickability test, lump and total meat yields, bacteriological quality, palatability test, and shelf-life of the picked crabmeat.

Meat picked from crabs which had been frozen by both methods was found to be acceptable to a taste panel in terms of flavor, texture, and appearance. Meat yields were comparable between frozen crabs and fresh crabs picked on the same day. The quality of the lump meat appeared to be unaffected by the freezing process. Bacteriological quality of the meat picked from the frozen crabs was good and the keeping quality of the meat was excellent.

Viral Evaluation of Prohibited Oyster Growing Waters (Funded by M-ASGP): This joint project with the University of Southern Mississippi is designed to assess the relationship between numbers of pollution-indicator bacteria in the water and the level of viruses found in the oysters. GCRL is responsible for water- and oyster-sample collections and bacteriological analysis. Data produced in this project will be available to State and Federal regulatory agencies for use in assessing present-day water quality standards.

Environmental Baseline Survey of St. Louis Bay: Microbiological Investigations (Funded by Du Pont): Water samples from 14 stations in the Bay and adjacent rivers are being collected at 2-week intervals and analyzed for coliforms and fecal coliforms. These data will document the present-day levels of sewage pollution in the Bay. Each month water samples collected at 22 stations are analyzed for microbial biomass using adenosine triphosphate (ATP) methodology. These data will be used to correlate with phytoplankton counts and productivity measurements.

Populations of selected groups of bacteria are being studied in sediments from seven locations around the Bay. Metabolic activity rates and total biomass are being determined.

A Study of the Genus Bacillus in Marine and Estuarine Sediments (Funded by GCRL): The distribution, taxonomy and ecology of the genus *Bacillus* in the estuarine sediments of St. Louis Bay are being investigated. The numbers of *Bacillus* spores found at seven locations in the Bay are being enumerated monthly and the percentage of pigment forms noted. Thirty isolates are being selected from each of three stations monthly for future taxonomic studies.

The Determination of the Acute Toxicity of Dredged Material to Fish and Microinvertebrates under Standard, Static, Bioassay Conditions (Funded by GCRL): Sediment samples collected from the inner harbor and approach channel to the Broadwater Beach Marina in Biloxi, Mississippi, were processed in accordance with U.S. Environmental Protection Agency (EPA) guidelines and tested as toxicants to blue crabs, mysid shrimp, and penaeid shrimp. As stated in last year's report, no deaths were observed with the blue crab, and mysid shrimp mortalities were random and not associated with sediment (toxicant) concentration. During fiscal year 1978, further tests were conducted with brown shrimp. Mortalities were random and not related to sediment concentration.

The information generated by these investigations was utilized by the Broadwater Beach Marina in obtaining the permits required to perform maintenance dredging in their harbor.

Persistence and Degradation of Insecticides in Estuarine Water and Sediment (Funded by GCRL): Investigations

regarding the persistence and degradation of malthion, parathion, methyl parathion, diazinon, and mirex in the estuarine environment were curtailed during fiscal year 1978 to allow time for the other toxicology investigations described elsewhere in this report. Bacterial cultures capable of degrading the organophosphorus insecticides are being maintained for future use.

Insecticide Persistence in Natural Seawater as Affected by Salinity, Temperature, and Sterility (Funded by EPA): This investigation was conducted in conjunction with studies underway at the EPA Laboratory at Gulf Breeze, Florida, in an attempt to more clearly delineate the various biological and chemical factors that determine the recalcitrance of insecticides in the natural environment. This project was actually completed in fiscal year 1977 with the final report being prepared during fiscal year 1978.

MICROSCOPY SECTION, Dr. Harold D. Howse, Head

Studies on Lymphocystis Virions (Funded by GCRL): Studies of lymphocystis tumors continued with the collaboration of the Parasitology Section. Tumors were examined from different species of fishes, several of which were new host species. Diameters of the virions examined in each species were as follows: 387 nm *Pomancanthus semicirculatus*, Koran angel fish; 287 nm *Zanclus canescens*, Moorish idol; 287 nm *Chaetodon capsitratus*, foureye butterfly fish; 259 nm *Platax orfiendaris*, batfish; and 287 nm *Holancanthus ciliaris*, queen angelfish.

Further studies are in progress on cellular response to this viral pathogen in different fish species.

Histological and Cytological Investigation of Various Organs and Tissues of the Atlantic Croaker Micropogonias undulatus (Funded by GCRL): The first phase of a histological and cytological study was begun on the several organ systems and tissues of the Atlantic croaker. Numerous juvenile fish were processed and sectioned in longitudinal and cross-sectional views for selective staining. Additionally, various selected tissues were excised from sexually mature specimens and prepared for comparison of seasonal changes.

The second phase of this project will consist of the preparation of an atlas of normal croaker histology and cytology. The results of this study will provide the basis for determining pathological changes occurring in croakers exposed to various toxicants under experimental conditions.

Fine Structure of the Peritrichous Ectocommensal Zoothamnium sp. (Funded by GCRL): This project, conducted in collaboration with T. G. Sarphie and W. E. Hawkins, University of South Alabama, dealt with a protozoan that attaches to gills of penaeid shrimp. When present in large numbers, these ectocommensals can suffocate commercially important shrimp and cause severe economic problems in aquaculture. The results of this study are presented in a paper now in press.

OYSTER BIOLOGY SECTION, Dr. Edwin W. Cake, Jr., Head

Oyster Spat Monitoring Program (Funded by GCRL): This study concluded 2 years of oyster "spat" monitoring to determine the time and intensity of setting at five locations in Mississippi Sound and adjacent waters. The study also provided information on the setting time and density of major oyster competitors and foulers, such as barnacles. These data collected to date are being provided to oyster culturists who wish to plant cultch material for collecting seed oysters on private leases.

Plankton Sampling for Oyster Larvae (Funded by GCRL): This is the second and final year of a study to monitor the number of oyster larvae in Biloxi Bay plankton as a means of estimating spawning activity and potential spat settlement. The data gathered should assist oyster biologists and the oyster industry in predicting the best time for planting cultch materials.

Oyster Growth and Mortality Study (Funded by GCRL): This is also the last of a 2-year study to determine the growth and mortality rates of various types of seed oysters at five locations in Mississippi Sound and adjacent waters. Oysters reared in lagoons on the barrier islands appear to grow faster and survive better than those "planted" at inshore locations. The reproductive processes for all seed-oyster types appear to be normal for the salinity and temperature regimes at all five locations.

Biological and Ecological Studies of the Oyster Boring Clam (Funded by GCRL): The final year of a 3-year investigation was completed on the basic biology and ecology of *Diplothyra smithii*. Its life cycle has been documented and its burrowing behavior and mechanisms have been observed and documented. Distribution and population dynamic data from Mississippi Sound burrowing clams are being assessed. The reproductive biology including the gonadal, spawning and setting cycles have been documented. Morphological studies of the adult clams have also been completed.

Gametogenesis and Spawning of Mississippi Sound Oysters (Funded by GCRL): During the last year of this 2-year study, monthly and bimonthly gonad samples of oysters from western Mississippi Sound were examined to determine the effects of temperature and salinity on annual spawning cycles. The results of this study should aid in our understanding of the basic reproductive biology of Gulf Coast oysters.

Black Drum Predation on Oysters and Other Invertebrates (Funded by GCRL): This 3-year study was completed during the past fiscal year. It provided the first experimental documentation of the predatory behavior and predation rates for this little-known species. Under experimental conditions, large drum will consume approximately one oyster per-pound-of-body-weight per day. The black drum is, therefore, perhaps the most destructive oyster predator in Mississippi Sound.

Oyster Depuration in Mississippi: Environmental, Legal and Management Assessments (Funded by M-ASGP and GCRL): The first phase of a 3-year study was completed during the past year and the final report will be available to the public during fiscal year 1979. Results of the study indicate that there are no insurmountable environmental, legal, or management problems that would preclude the operation of onshore oyster depuration facilities in Mississippi and Alabama. The study did identify problem areas, including a lack of State regulations that would be required to operate a State-approved depuration plant. Draft regulations are included in the final report for consideration by the Mississippi Legislature and the U.S. Food and Drug Administration.

Oyster Depuration in Mississippi: Engineering Assessments (Funded by M-ASGP and GCRL): The second phase of a 3-year study was initiated during fiscal year 1978 in cooperation with sanitary engineers from Mississippi State University. During the study, a 2-bushel, pilot depuration facility was constructed and operated at the GCRL Oyster Biology Facility on Pt. Cadet in Biloxi. Preliminary results indicate that oyster waste products (feces and pseudofeces) can be removed continually during the depuration process and treated via presently acceptable sanitary methods. This reduces the need for complete daily wash-downs, which are expensive, and energy- and time-consuming.

Off-Bottom Cleansing of Oysters in Mississippi Sound (Funded by GCRL): A 2-year study was initiated during the fiscal year 1978 to compare off-bottom and on-bottom cleansing (relaying) of oysters. New techniques and devices are being utilized in an attempt to reduce loss of relayed oysters during cleansing by holding them in off-bottom, containerized storage. The method holds promise for that segment of the oyster industry which is now relaying oysters to leasing bottoms in approved shellfish waters, and which is suffering considerable oyster losses due to burial, predation, rough handling, etc. This study is expected to benefit the entire oyster industry by increasing harvestable oyster stocks and reducing expenses.

Oyster Mariculture (Funded by GCRL): Current experimental oyster mariculture involving one seed oyster hatchery includes, but is not limited to, the following: out-of-season conditioning and spawning of Mississippi Sound oysters; experimental raceway and tank culture of hatchery-reared seed osyters; engineering design and evaluation of experimental hatchery methods; evaluation of new cultch materials for hatchery-reared seed oysters; the effects of various predators (crabs, black drum, spiny boxfish) on seed oysters; and the feasibility of utilizing natural spatfall to increase seed production using Mahes and shell spat collectors.

PARASITOLOGY SECTION, Dr. Robin M. Overstreet, Head

Parasites of Commercially Important Fishes (Funded by NMFS and GCRL): The project primarily concerns the use of parasites to indicate migratory and feeding behavior of the Atlantic croaker. Feeding habits of several other local finfishes are also being investigated by analyzing stomach contents. The project additionally covers aspects of the effects of selected parasites on their respective hosts.

Handbook of Marine Parasites of the Northern Gulf of Mexico (Funded by M-ASGP and the State of Mississippi): This project terminated in January 1978, resulting in an illustrated guidebook for students and laymen to help them understand some of the common parasites likely to be encountered in local finfishes and shellfishes.

Gulf Coast Survey of Fish and Shellfish for Parasites Pathogenic to the Human Consumer (Funded by the U.S. Food and Drug Administration): The purpose of the project was to survey four finfishes and four shellfishes seasonally from Mississippi, Texas (Galveston) and Florida (Tampa) for ascaridoids, heterophyids, and other parasites of public health importance. Representatives of those parasites found were fed to mice and other mammals to determine their ability to live in or cause pathological changes in the hosts. The project terminated 30 June 1978.

Pathological Effects of Larval Thynnascaris Nematodes in the Rhesus Monkey (Macaca mulatta) (Funded by the U.S. Air Force): The primary purpose of the study was to determine if one of the common larval nematodes (*Thynnascaris* Type MB) causes pathological alterations in the alimentary tract of a monkey.

Studies on Helminths of the Northern Gulf of Mexico Region (Funded by GCRL): A determination of parasites in hosts involved in the above projects as well as other hosts are included in this study. This included life histories of the parasites and the relationships between a parasite and its host.

PHYSICAL OCEANOGRAPHY SECTION,
Mr. Charles K. Eleuterius, Head

Wave Refraction Analysis (Funded by M-ASGP): Loss of life and erosion of valuable waterfront property have been attributable to an adverse wave climate in Mississippi Sound and on the seaward side of the barrier islands. Applying a computer wave-refraction model, utilizing linear-wave theory, to a uniform bathymetric grid of the study area generates refraction diagrams. These diagrams, when interpreted, show the locations of high-energy areas and wave caustics under varying wave climates. This information will be useful in marine navigation, especially to the inexperienced boat operator, and to landowners and engineers in employing methods to prevent further erosion of waterfront property.

Characterization of Tidal Bayou and Development of Statistical Evaluation/Monitoring Techniques (Funded by GCRL): This is a continuing study of a critical area of estuarine systems, the contributary – especially the tidal bayou. To ascertain the most useful parametric statistics to characterize the system, data have been collected for the past 4 years. In addition to establishing baseline statistics, statistical techniques are being developed for monitoring

the bayous for changes that might ordinarily go unnoticed.

Air–Sea Heat Flux (Funded by GCRL): Water temperature is an important factor in the growth and migration of marine species. Attempting to forecast an opening date for shrimping season based on a statistical shrimp size is hampered by the variability in growth rate which is dependent, in part, on the water temperature. This study includes the development of a predictive, stochastic model of heat flux in Mississippi Sound that will provide a means of predicting the thermal structure of the water column when given a set of conditions.

Hydrology of St. Louis Bay (Funded by Du Pont): The objective of this study is the development of an extensive and intensive baseline of hydrographic parameters to serve as an estimate for "normal" conditions. The field data collection effort, which is coordinated with the other disciplines participating in the environmental baseline study, obtains measurements of water temperature, salinity, pH, dissolved oxygen, turbidity and water color. In addition, fixed and automated sampling platforms continuously record wind speed and direction, water elevations, air temperature, photic period, pH, dissolved oxygen, salinity and water temperature.

The continuous records of tides and winds, supplemented by direct-current measurements, will be used to calibrate a mathematical model of water circulation for St. Louis Bay.

The product of the Bay study will be a viable mathematical algorithm of circulation, determination of flushing rate, physical characterization, baseline (norm) of some physical property levels, and quantification of some physical processes.

PHYSIOLOGY SECTION, Dr. A. Venkataramiah, Head

Evaulation of the Nutritional Value of Grass from High Marsh Areas to Brown Shrimp Penaeus aztecus Ives (Funded by MMRC): The objectives of this study were to determine the feasibility of utilizing the high marsh grass *Spartina patens* and shrimp shell waste in shrimp culture as supplementary feeding. The food pellets composed of modified grass with a maximum of 4% protein and shrimp shell waste gave a greater increase in biomass than the pellets composed exclusively of grass. Control pellets produced a slightly better growth than the grass pellets. Shrimp provided with loose grass and shrimp shell waste showed a tendency toward high cannibalism.

The use of microbially modified *Spartina patens* as a food source does not appear feasible, at least in laboratory shrimp culture. With more effective decomposing techniques, high marsh grass may prove useful for the production of detritus in pond culture. Addition of shrimp shell waste to the food appears to improve growth and survival, and warrants further investigation.

Acute Effect of the Simulated Du Pont Effluent on the Survival and Behavior of Penaeid Shrimp (Funded by GCRL): The acute effect of simulated Du Pont waste was tested on the mortality rates, behavioral responses of juvenile brown shrimp *Penaeus aztecus*, during 96- and 144-hour exposure in 10, 20, 35, and 50% effluent concentrations at 80, 86 and 90°F. Control shrimp normally survived during the 96-hour period. A few of the unfed, but not the fed, shrimp died in 144 hours at 86 and 90°F. Survival was good in 50% effluent concentrations except that one death occurred at 90°F in 96 hours. Some of the starved shrimp died at 86 and 90°F. A few of the fed animals also died in 10 and 35% effluent concentrations without showing any correlation between the concentration of effluent and mortality. While high temperature by itself is known to be detrimental to their survival, addition of effluents to the medium may augment the adverse effects at high temperature.

A Literature Research Project on the Lethal Upper Temperature Limits for Coastal Water Fauna (Funded by GCRL): About 400 new references have been added to the existing 1,200 or so previously collected for the purpose of compiling a reference book.

Effect of Simulated Du Pont Effluent on the Physiological Responses of Commercial Penaeid Shrimp (Funded by GCRL): Preliminary experiments were done with a Warburg respirometer to determine the effect on the O_2 consumption in brine shrimp infected with the bacteria, *Leucothrix* sp. With the existing respirometry techniques no significant differences were found between the normal and bacterially infected brine shrimp.

Caloric Densities of some Shellfish Meat Fats (Funded by GCRL): The caloric content of meats of crab, lobster, three species of shrimp, crawfish, oyster and squid was analyzed by oxygen-bomb calorimetry. Whole meat of lobster yielded the lowest calories and that of squid the highest calories. The percentage of fat content in the meats differed significantly; oyster meat has more fat than the other shellfish meats analyzed, and crawfish very low fat.

The caloric content of the extracted fat differed distinctly among the species. Fats of squid and lobster showed very low-caloric energies while fats of oyster, blue crab and pink shrimp showed high-caloric energies. It is suggested that the nature of the lipid classes contributes more toward caloric density of the tissue than the total lipid content.

Size-Related Variations in the Tissue Cholesterol Content of the Brown Shrimp Penaeus aztecus Ives (Funded by GCRL): Muscle (tail) cholesterol increased linearly as body weight increased among female shrimp, whereas males maintained a steady level independent of size. Based on these findings, it is suggested that the bulk of marketable shrimp, 60–68 heads-on count/pound, have relatively lower cholesterol levels than is reported in nutritional and medical literature. Compared to caviar, organ meats, brains and eggs, shrimp muscles showed a low cholesterol content.

Effect of Cooking and Frozen Storage on the Cholesterol Content of Selected Shellfish (Funded by GCRL): Cooking decreased the cholesterol content of crabmeat but

brought about no significant change in shrimp or oyster meat levels. Freezing and thawing of raw tissue increased cholesterol content of oyster and shrimp meats but did not affect the level in crabmeat.

Lipid and Sterol Levels as Indices to Determine the Optimum Harvestable Size in Crassostrea virginica (Gmelin) (Funded by GCRL): The lipid content of the meat was directly related to size on a logarithmic scale and was independent of sex. The relationship between total sterol content and weight of oysters was nonlinear. Adult males show higher sterol content than females. It is suggested that oysters with an 8 to 10 g meat weight or 95 to 100 mm shell length would be ideal for harvest because oysters in that size range have low sterol and triglyceride levels.

SYSTEMATIC ZOOLOGY SECTION , Mr. C. E. Dawson, Head

Systematic Studies on Fishes of the Families Microdesmidae, Dactyloscopidae and Syngnathidae (Funded by the National Science Foundation): Studies on three families of fishes continued throughout the year. Revisionary studies on the pipefish genera *Penetopteryx* (and relatives), *Hippichthys* and *Bhanotia* were completed. Revisions of *Oostethus, Doryichthys* and related genera, as well as reviews of the western Atlantic pipefishes (Syngnathidae) and sand stargazers (Dactyloscopidae), also continued throughout the year. In connection with these problems, studies were conducted on fishes at the California Academy of Sciences and National Museum of Natural History.

SPECIAL FACILITIES

MARINE EDUCATION CENTER, Mr. Gerald C. Corcoran, Curator

Visitations to the Marine Education Center increased from 23,844 in fiscal year 1977 to 39,155 in fiscal year 1978. While some of the increase may be attributed to the opening of the new Gulf Marine State Park, the majority must be considered as normal average yearly increase.

In cooperation with the M-ASGP, four workshops in marine science were conducted for inland teachers. These were held in Oxford and Jackson, Mississippi, and Huntsville and Montgomery, Alabama. Emphasis was placed on the use of inland facilities in conducting classes in marine education. The primary aim of the workshops was to acquaint teachers with the concept that "marine" is now generally accepted as referring to water in general and not necessarily salt water. Approximately 120 teachers attended the workshops.

At the request of a Slidell, Louisiana, parents group, a course in marine science for gifted children was written. The presentation of the course took place in July 1978. Subjects covered were coastal geography, the Gulf of Mexico as a habitat, diversity of marine life, water mammals and identification of selected specimens. Field trips were scheduled to augment and supplement classroom discussion.

The ongoing marine science courses for teachers had a total enrollment of 44 students, 26 in the basic course and 18 in the advanced course. As in previous years, enrollment included people in occupations other than teaching. Included were one Navy commander, one chemist, two Air Force retirees, one Veterans Administration Hospital employee and three housewives.

A slide program and field trip to Horn Island were conducted for a class of teachers from Tougaloo College. This was another attempt to introduce marine science to inland teachers. Eight students were involved, and, although the study consisted primarily of saltwater animals, the students were instructed in the general characteristics of plants and animals. Techniques for adapting the information to fresh water were emphasized.

The student-intern program was continued with two students from Gulfport and one from Biloxi participating. Students were given credit through their schools for advanced biology. Subjects covered were identification of animals, care and maintenance of captive specimens,and preservation.

The special educational program for Creative Learning in Unusual Environments groups from Memphis, Tennessee, was conducted again this year with a total of six groups taking part. This program is growing each year. The Whitehaven Methodist Day School, Memphis, took advantage of the program by bringing a group to the Center for the fourth consecutive year. The Marine Education Center makes arrangements for these groups to attend Marine Life in Gulfport, tour the Biloxi harbor,and go seining on the beach at night, in addition to their visit to the Center exhibits.

Two Explorer Posts in Environmental Science were formed during the year under the auspices of the Boy Scouts of America program. Programs such as water sampling techniques and fish identification were presented. Center personnel continued to act as merit badge counselors to the Boy Scouts of America on 16 different merit badges. The Explorers were taken on field trips to the local beach for collection of specimens and water samples. Equipment and literature at the Center were utilized to conduct programs for the Scouts. Future plans call for a session on ecology with a possible trip to Horn Island to study a special ecological habitat.

Three radio programs on marine-related subjects were presented in cooperation with radio station WGCM in Gulfport. The topics included sharks, poisonous marine animals and local snakes. Two programs, in cooperation with the Public Information Section of the Laboratory, which included aquaria of horseshoe crabs and a film showing, were conducted for local libraries in Pascagoula and Moss Point, Mississippi.

Consultations continued between the Marine Education Center and Marine Life, Inc. of Gulfport. The veterinarian responsible for administering to marine mammals at Marine Life has been assisted on several occasions by Center personnel. Local pet shops utilize the services of the Center in dealing with outbreaks of diseases in their aquariums.

Visitors request, and are provided, information concerning correct aquarium maintenance procedures, fish diseases and snake handling. Local hospitals routinely send snakes to the Center for positive identification prior to dealing with snake bite cases. One out of two snakes proved to be poisonous during the past year.

The Marine Education Center contributes to the publication of the National Marine Education Association entitled *Current* and the Curator edits a monthly newsletter, *Lateral Line*, published by the North American Native Fish Association. Mr. Corcoran was selected as "Conservation Educator of the Year" for the State of Mississippi by the Mississippi Wildlife Federation.

THE GUNTER LIBRARY, Mr. Malcolm S. Ware, Senior Librarian

A record amount of binding was done this year with long backruns of 39 journal titles being bound. Nineteen monographs were also bound. A number of rare and out-of-print titles were secured, among which were three notable titles: Gurney's *British Fresh-Water Copepoda* (in three volumes); Moore's *Condition and Extent of Natural Oyster Beds . . . Mississippi and Alabama*; and *The Microtomists (Vade-Mecum)*. Another important purchase was a backrun of the *Discovery Reports* on microfiche, purchased from E. P. Group of Companies in England.

Backruns of journals were strengthened in 49 titles. Thirty-nine new journals were added, 21 as standing orders. Two new sections were established within the collections; i.e., Environmental Impact Statements, and the Piatt Reprint Collection.

Four hundred fifty books were purchased during the year, and donations further strengthened library holdings. Dr. B. H. Atwell of the Earth Resources Laboratory, Slidell, Louisiana, donated runs of journals in ten titles, 36 books and 60 reprints. Dr. P. A. Isaacson of the Department of Public Services, Albany, New York, donated 549 scientific papers which included some journal numbers. Dr. R. E. Baglin, Jr., of National Marine Fisheries Service, Miami, Florida, donated books and reprints numbering collectively 280. Staff members making donations to the library included Drs. David W. Cook, Gordon Gunter, Harold D. Howse, Ervin G. Otvos and Mr. John P. Steen, Jr.

Five hundred thirty-six reprints were cataloged and shelved, adding to the approximate total of 20,000 processed reprints. (There are still an additional 5,000 to 8,000 unprocessed reprints backlogged.) The book cataloger processed about 500 books (October–June) bringing the cataloged portion of the book collection up to about 35% of the total. Incoming interlibrary loans numbered about 196 and more than 70 items were loaned out to other libraries. A year-end survey revealed that the new card catalog and microfilm filing cabinets were 65% filled. The microfiche system was 25% filled in its present mode.

Visiting researchers used the Gunter Library in increasing numbers this year, coming from three laboratories at Dauphin Island and the Pascagoula fishery station. Other visiting researchers were from various Mississippi and Alabama colleges and universities, as well as from local and regional agencies such as Geo-Marine, Richardson, Texas; National Space Technology Laboratory, Bay St. Louis; Ingalls Shipbuilding Division of Litton Industries, Pascagoula; and Jackson County Planning Commission, Pascagoula. During the fall and spring, field-trip groups from affiliate schools used the collection on a one- and two-week basis. In addition, a record number of science fair students came to the library from the junior and senior high schools of the six coastal counties. Also, college-level students enrolled in continuing education courses at the Marine Education Center and on the main campus, used the library every quarter. Throughout the year various researchers, both U.S. and foreign, were hosted on a "walk-in" basis.

ICHTHYOLOGY RESEARCH MUSEUM, Mr. C. E. Dawson, Head

Four hundred twenty-two lots, representing approximately 5,000 specimens were cataloged.

An important collection of fishes by the R/V OREGON off the coasts of Venezuela and Brazil was received from the NMFS. Gifts of specimens, including a number of pipefishes, were received from several U.S. and foreign institutions. The Museum now houses one of the world's most comprehensive collections of pipefishes.

Loans of specimens were made to a number of U.S. and foreign institutions. Identifications were provided for fishes sent by investigators in the U.S., Central and South America, Europe, Australia, etc.

WATER ANALYSIS LABORATORY, Dr. Thomas F. Lytle, Head

The Water Analysis Laboratory has processed samples for the sections of Physical Oceanography, Microbiology, Oyster Biology, Botany, Anadromous Fishes; for the Du Pont project and the Mississippi Air and Water Pollution Control Commission. These analyses have included: orthophosphate, total phosphorus, nitrate, nitrite, ammonia, sulfate, silicate, chloride, turbidity, suspended solids, alkalinity and chlorophyll, and phaeophytin. In all, 2,635 analyses have been performed (excluding those for the Du Pont project). Many of the analytical schemes have been modified to comply with Federal guidelines. In addition to actual analyses, staff of the Water Lab have advised other section members and persons outside the Laboratory on matters of pollution, water-quality criteria, sample collection, etc. Some of the teaching for the Laboratory's courses, Special Problems in 1977 and Special Topics in 1978, was handled by Water Lab personnel.

COMPUTER SECTION, Mr. David Boyes, Head

Several significant events occurred during the year. Foremost was the use of on-site data retrieval systems for scientific analysis. Production run time, the actual amount of time the computer is used for analysis, increased to 75%

of total run time, the amount of time the computer was in operation. Work on multidimensional statistical analysis and graphical programs departed from the development stage and entered the test-and-application stage.

The training program for section personnel has proven to be an effective tool for increasing the performance of the Computer Center. Tasks that could only be performed by one individual can now be undertaken and accomplished (with a small loss in overall efficiency) by another member of the section. The net result is a decrease in computer down-time.

The total number of jobs, programs run on the computer, for the year was about 2,266, which required a total of 1,084.69 hours. The following projects (sections) were the main users: Fisheries, 386 jobs; Du Pont project, 386 jobs; Finance, 310 jobs; Graduate program 289 jobs; Oceanography, 250 jobs; Botany, 98 jobs; Systematic Zoology, 94 jobs; and Parasitology, 59 jobs.

PUBLIC INFORMATION/PUBLICATIONS SECTION
Miss Catherine Campbell, Head

News releases were sent to 50 selected daily and weekly newspapers, television and radio stations, wire services and special correspondents. In addition, pictures of field-trip groups and summer college students were made and sent to hometown and campus publications. A general article on the Laboratory was furnished the *Mississippi Press Register* (Pascagoula) for a special edition printed in March. Assistance was also provided to outside writers, photographers and television crews in obtaining interviews with members of the Laboratory staff.

A 4-day open house was planned and held November 9–12, 1977. The first three days were devoted to junior and senior high school science students and about 530 students and teachers participated. The final day, Saturday, was for the general public and over 650 visitors attended. Not all interested science classes could attend open house and they requested Laboratory tours at other times, including six college and eight secondary school groups.

Through visits to public libraries in the coastal communities, in June 1978 the Section began a new public information program entitled "What's in the Gulf for you?" This was planned originally as a summer activity, however, it will be continued as long as interest warrants. Depending on the size and hours of the libraries visited, staff members of the Section and of the Marine Education Center spend up to 7 hours on a visit. The Marine Education Center also provides an aquarium with a live horseshoe crab for the visits. Color slides explaining the processing of seafood in local plants and a 16-mm sound film "World Beneath the Sea" are shown; Marine Education Leaflets, tide tables, shark recipes, marine career information, and other free materials are distributed. Visitors and library personnel are made more familiar with the programs and activities of the Marine Education Center, the Laboratory, and its publications.

From July 1, 1977 until January 8, 1978, the Section produced 19 new 15-minute "On Course" radio programs and 9 rerecorded programs. Programs were broadcast by nine radio stations along the coast and in Meridian and Jackson. In January, after completing 2 full years of broadcasts, the Section began a year's vacation from the radio series.

Living Science Comments, a new program, was undertaken at the request of the Director to preserve for future generations the voices and comments of outstanding scientists. Two recordings have been made, the first of Dr. Gordon Gunter of this Laboratory, and the second of Dr. J. Frederick Walker, former professor at the University of Southern Mississippi, now retired. Master tapes will be maintained and duplicated as needed.

Color slides and black and white pictures were made of field sampling activities in connection with the environmental baseline survey of the Bay of St. Louis, conducted by the Laboratory for Du Pont. A slide program is to be assembled with narration; black and white prints were used in *Marine Briefs*, GCRL's monthly newsletter. Additional color slides were made in crab processing plants for the cooperative seafood industry program series and the narration was revised.

For the first time class pictures were taken for the summer courses taught at the Laboratory. Students and professors were given an opportunity to purchase prints and others will be available in an album in the Gunter Library.

The Section staff provided Laboratory participation in the Mississippi State University-sponsored Harrison County Fair at Edgewater Mall Shopping City in September 1977; also, in the Mississippi Academy of Sciences annual meeting exhibits in Biloxi during March 1978.

Copy was edited and set in page format and illustrations prepared for printing the December 1977 issue of *Gulf Research Reports*, Volume 6, Number 1. Finished copies were received in April and 758 copies were mailed by the staff. The issue contained seven regular papers, six short communications and the Director's summary report of Laboratory activities. After materials for this issue went to the printer, work began on the next issue, Volume 6, Number 2.

Similar publications work was performed by the staff on the *Technical Report Series*. Number 2 of the series, *The Shrimp Fishery of the Gulf of Mexico United States: A Regional Management Plan*, was published in August 1977. *Technical Report Series*, Number 2, Part 2, a condensed form of the management plan, was published in November 1977. Distribution of both was handled primarily by Mr. J. Y. Christmas, Assistant Director of the Laboratory for Fisheries Research and Management, who served as co-editor with Dr. David Etzold of the University of Southern Mississippi.

Section personnel wrote and edited copy, took photographs, set copy and made layouts for 12 monthly issues of

Marine Briefs, the Laboratory newsletter. This was the seventh year of publication; about 3800 copies are distributed regularly.

ACADEMIC PROGRAM

NEW AFFILIATE

One institution became affiliated with the Laboratory during the year for the purpose of training its students in the marine sciences, bringing the total of out-of-state affiliates to 38. This new affiliate is Middle Tennessee State University, Murfreesboro, Tennessee.

SUMMER SESSION, Dr. David W. Cook, Registrar

The 1977 summer academic session involved 91 students registering individually for a total of 125 student courses. Forty-nine students registered through Mississippi schools, 65 through out-of-state affiliates and 10 through nonaffiliated out-of-state institutions. Formal courses offered during the 1977 session were:

- Marine Chemistry, Drs. Julia S. Lytle and Thomas F. Lytle, staff
- Salt Marsh Ecology, Dr. Lionel N. Eleuterius, staff
- Physical Marine Geology, Dr. Ervin G. Otvos, staff
- Chemical Marine Geology, Drs. Ervin G. Otvos, Julia S. Lytle, and Thomas F. Lytle, staff
- Marine Microbiology, Drs. David W. Cook and William W. Walker, staff
- Introduction to Marine Zoology, Dr. Buena S. Ballard, Southwestern Oklahoma State University
- Marine Vertebrate Zoology and Ichthyology, Dr. J. William Cliburn, University of Southern Mississippi
- Marine Invertebrate Zoology, Dr. Edwin W. Cake, Jr., staff
- Marine Fisheries Management, Mr. J. Y. Christmas, staff, and visiting specialists
- Marine Aquaculture, Dr. Edwin W. Cake, Jr., staff
- Marine Ecology, Drs. James T. McBee and Robert A. Woodmansee, staff
- Marine Botany, Dr. R. B. Channell, Vanderbilt University
- Special Problems in Marine Science, staff

During the 1977–78 academic year, 44 students earned credit in courses in marine science for teachers that were offered through the Marine Education Center located in Biloxi. Courses offered were:

- Basic Techniques in Marine Science for Teachers, Mr. Gerald C. Corcoran, staff
- Advanced Studies in Marine Science for Teachers, Mr. Gerald C. Corcoran, staff

GRADUATE RESEARCH PROGRAM

Courses offered in the Graduate Research Program during this period in which students participated included: Seminar, Special Problems in Marine Science, Special Topics in Marine Science and Graduate Research in Marine Science. A total of 101 semester hours credit were earned by these students.

The Graduate Research Program has seen significant growth during the year with the addition of seven new students. One student completed his degree and four students have completed their research projects and returned to their parent campuses for further coursework. Fourteen students in the program were candidates for the master's degree and eight candidates for the doctorate.

Each candidate's name, thesis title, degree sought and home university are listed below according to research sections directing their work:

Anadramous Fishes Section: William W. Falls, "Food habits and feeding selectivity of larval striped bass, *Morone saxatilis* (Walbaum), under intensive culture," Ph.D., University of Southern Mississippi.

Analytical Chemistry Section: Leo N. Richard, "The presence of aromatic hydrocarbons and bena(a)pyrene in Mississippi Gulf Coast oysters," M.S., University of Mississippi.

Botany Section: James C. Garrison, "Some relationships of salt marsh vegetation to abundance of the marsh periwinkle *Littorina irrorata* Say," M.S., University of Mississippi.

Stephen H. Sky-Peck, "A study of growth and nitrogen content of *Spartina alterniflora* and *Juncus roemerianus* in response to source and concentration of nitrogen," M.S., University of Mississippi.

Ecology Section: Jerry A. McLelland, "The summer vertical distribution of Chaetognatha in the northeastern Gulf of Mexico," M.S., University of Southern Mississippi.

John P. Steen, Jr., "Factors influencing the spatial and temporal distribution of selected crustacean plankton species in Davis Bayou," Ph.D., University of Mississippi.

Michael C. Torjusen, "The occurrence of planktonic larval and postlarval fishes in waters of the northern Gulf of Mexico and the Mississippi Sound," M.S., University of Mississippi.

Oyster Biology Section: David H. Barnes, "Polychaetes associated with an artificial reef in the north central Gulf of Mexico," M.S., University of Southern Mississippi.

David A. Blei, "A successional study of the hydrozoans inhabiting an artificial reef in the north central Gulf of Mexico," M.S., University of Southern Mississippi.

Neil Cave, "Predator-prey relationships involving the American oyster, *Crassostrea virginica* (Gmelin), and the black drum, *Pogonias cromis* Linnaeus, in the Mississippi Sound," M.S., Southeastern Louisiana University.

Alfred P. Chestnut, "Substrate competition between *Crassostrea virginica* (Gmelin) and associated sessile marine invertebrates," Ph.D., University of Southern Mississippi.

John D. Demond, "Amphipod fouling of an artificial reef in the north central Gulf of Mexico," M.S., University of Southern Mississippi.

Katherine A. McGraw, "A comparison of the growth and survival rates of hatchery-reared and natural oyster spat at

selected locations in the Mississippi Sound and adjacent waters with comments on the biology of oysters in Mississippi," Ph.D., University of Washington.

John E. Supan, "A comparison of 'off-bottom' relaying oysters in the Mississippi Sound," M.S., University of Southern Mississippi.

Parasitology Section: Daniel R. Brooks, "Systematic studies on the digenetic trematodes of crocolilians with emphasis on the family Acanthostomidae," Ph.D., University of Mississippi.

Thomas L. Deardorff, "Nematodes of the genus *Thynascaris* Dollfus 1933, (Anisakidae) in the northern Gulf of Mexico," Ph.D., University of Mississippi.

Alan C. Fusco, The life cycle and development of *Sirocamallanus* sp.," M.S., University of Southern Mississippi.

Tom E. Mattis, "Larval development of two trypanorhynch tapeworms from Mississippi Sound," Ph.D., University of Southern Mississippi.

Mobashir Ahmad Solangi, "Pathological changes in some estuarine fish exposed to crude oil and its water-soluble fractions," Ph.D., University of Southern Mississippi.

Physiology Section: Ann L. Gannam, "Effect of replacing dietary animal protein with plant protein supplemented by methionine on the growth and survival of Penaeid shrimp," M.S., University of Southern Mississippi.

Shiao Yu Wang, "Studies on the effect of size and temperature on the respiration rates of brown shrimp, *Penaeus aztecus* Jues, in declining oxygen tension," M.S., University of Southern Mississippi.

Zubir Bin Din, "The food and feeding habits of the common bay anchovy, *Anchoa mitchilli diaphara* Hildebrand," M.S., University of Mississippi.

SCIENTIFIC FIELD TRIP PROGRAM

As an adjunct to the teaching program, each year the Laboratory provides living accommodations, classroom laboratories, and essential services to visiting scientific field trip groups made up of college and university students and their professors. Such groups may stay for periods of up to several weeks, live in the dormitory, use Laboratory boats to make collections of marine life from the sea and from the beaches of offshore islands, and study their specimens in the classroom laboratories. During fiscal year 1978, the Laboratory was visited by 36 of these field trip groups. The total number of people involved were 537 professors and students who stayed an average length of 3.66 days. Some came as far as 2,000 miles to study the marine life of the Gulf of Mexico.

SPECIAL AND COMMUNITY SERVICES

FISHERY ASSISTANCE

A mixing chart for solutions made from 65% available chlorine dry compound was drawn up and distributed to seafood plants. A request had been received to establish the mixing ratios necessary to formulate 30-gallon quantities of 50-, 100-, and 200-ppm chlorine solutions for use in seafood plant operations. The charts were printed on waterproof paper. These charts were to take the guesswork out of formulating the three solutions.

A file of seafood regulations from the southeastern states was assembled. Frequent requests for specific information concerning out-of-state regulations are received from processors shipping seafood across state lines.

Visits to three Virginia seafood processing plants were arranged at the request of a Biloxi seafood packer. The Virginia plants briefly steam their oysters before they reach the shuckers. This causes the shell to open slightly, making it easier to cut out the meat, which increases the percentage of whole oysters to cut ones. The Biloxi packer was interested in introducing such a process in his plant if the process proved favorable, which it did.

Seafood Newsletter (Funded by GCRL): A monthly newsletter designed for seafood management personnel was established under the title *The Biloxi Schooner* honoring sailing vessels used in Mississippi's early seafood industry. The publication contains articles of pertinent information gathered from trade journals and scientific publications; Federal government publications; and notes taken at seminars, conferences, and trade conventions. The contents are technical and designed to be of practical benefit to those in the seafood business. Sixty copies are currently being printed and mailed to the industry.

Reorganized Mississippi Seafood Laws (Funded by GCRL): Mississippi's seafood laws were rewritten in simpler language for clarity; related regulations were grouped for better organization, and the two sets of laws were combined into a single text. This was done because the seafood industry has long had problems with understanding the regulations as they were originally published. The project's final draft was reviewed by the Mississippi State Board of Health after which copies were printed and mailed to the State's seafood processors.

Product Fact Sheet—Oysters (Funded by GCRL): At the request of the Mississippi Shellfish Packers, Inc., a Product Fact Sheet was written. Processors were having continuous problems with shipments of oysters being mishandled by distributors and retailers. Some type of educational material was needed to inform persons on how to care for oysters after they leave the processing plant. The Product Fact Sheet included information on the nutritional value of oysters, coloration variatons, and how to properly handle and merchandise them in commerce.

The Product Fact Sheet was composed in a photo-ready format and given to the president of the Mississippi Seafood Packers, Inc. Copies were to be printed and supplied to members for inclusion in shipments of iced oysters. It is hoped that distributors and retailers will read the sheet as they open the boxes. This information should help improve the shelf life of the product and reduce time and revenue

lost by the industry in picking up spoiled oysters from retail outlets.

Surveys were made on oyster beds at Gollott Oyster Farm to collect oysters for bacteriological studies, to check the salinity of the water over the bed, to count the number of oyster drills (conchs) on it and to establish the percentage of dead oysters resulting from oyster relaying operations.

It was the first year that the MMCC had issued private oyster leases to individuals or corporations. In these areas of good water quality, polluted oysters may be kept until they cleanse themselves, which takes about 15 days.

A trip was organized for several local seafood processors to attend a workshop for seafood retailers that was held in New Orleans. Afterward, a number of copies of the speaker's publication, *Operations Manual for the Seafood Retailer*, were ordered and distributed at their request to processors who could not attend.

A seafood processor was assisted in locating a safe, approved food preservative for trial use in packaged oysters.

Owners of two seafood retail markets requested and received assistance in evaluating their facilities. A list of suggestions was drawn up that would hopefully lead to an increased sales volume.

An oyster processor was assisted with the evaluation and selection of automatic packing equipment to be used in a planned plant expansion.

SEAFOOD SANITATION

Seafood Sanitation Program (Funded by GCRL): At the request of processors, the Microbiology Section makes plant inspections and collects samples for bacteriological testing to determine any problem areas. Suggestions are made for correcting any deficiencies noted in plant sanitation practices.

The program "In-Plant Sanitation–Crab Processing Plants," developed last year, has been upgraded and presented in several local plants to assist in the education and training of plant personnel.

During the fiscal year, 303 crabmeat and 222 oyster samples were collected and analyzed for aerobic plate, coliform and fecal coliform counts. In addition, all crabmeat samples were checked for *Escherichia coli*. This required over 800 hours of laboratory testing. Personnel traveled over 1,500 miles in collecting samples, visiting plants for evaluation and presenting programs.

ENVIRONMENTAL AFFAIRS COMMITTEE

This Committee is composed of all the senior scientific staff members at the Laboratory and is coordinated by the Ecology Section. The Committee provides an interdisciplinary approach to environmental problems in the wetlands and estuaries of Mississippi, primarily as a service to the MMRC, which partially funds this work. However, this Committee also cooperates with other State and Federal agencies on special projects that are not under the direct jurisdiction of the MMRC. The majority of this work deals with the review of permit requests for work proposed in the wetlands and estuaries. Committee members are asked for their comments and recommendations on each permit request. In most cases a site visit is made by representatives of the Committee. Based upon these inputs, a letter to the MMRC is drafted stating any objections the Committee may have, reasons for these objections and recommendations that may reduce or eliminate the objectives.

The Committee reviewed some 110 permit applications throughout the year. In addition, an environmental evaluation of an industrial discharge in Mississippi Sound was conducted and benthic samples were taken and processed for U.S. Fish and Wildlife Services personnel evaluating potential spoil areas for modification of the Pascagoula Ship Channel. Several members of this Committee were also involved in meetings with the Mississippi Air and Water Pollution Control Commission in conjunction with the Jackson County 201 Plan.

PUBLIC SEMINARS

The Gulf Coast Research Laboratory hosts a series of staff seminars throughout the year. These seminars are open to the public and speakers include invited scientists as well as officials from various levels of Local, State and Federal Government. The central purpose of the seminars is to promote better dissemination, understanding, and use of scientific information at all levels of society. Seminars presented during fiscal year 1978 were as follows:

"Current Research Efforts at E.P.A. Laboratory, Gulf Breeze, Florida" by Dr. D. R. Nimmo, U.S. Environmental Protection Agency, August 16, 1977.

"Water Hyacinth for Waste Water Treatment" by Mr. Bill Wolverton, Senior Research Scientist, National Space Technology Laboratory, September 20, 1977.

"Fishery Management in Mississippi–Its Progress and Needs" by Dr. Richard Leard, Director, Mississippi Marine Conservation Commission, October 4, 1977.

"Ectoparasites; Life on Man" by Mr. Alan Fusco, Parasitology Section, Gulf Coast Research Laboratory, October 18, 1977.

"Jellyfish Toxins: Mechanisms of Action" by Dr. Paul M. Toom, Associate Professor of Chemistry, University of Southern Mississippi, November 8, 1977.

"Effects of Slave Trade on Parasite Dispersal" by Mr. Tom Deardorff, Parasitology Section, Gulf Coast Research Laboratory, November 22, 1977.

"Antarctic, Land and Sea–Its Terrestrial and Marine Life" by Dr. Stephen Shabica, Research Oceanographer, National Park Service, December 6, 1977.

"Sharks and Stingrays in the Northern Gulf of Mexico" by Mr. Tom Mattis, Parasitology Section, Gulf Coast Research Laboratory, December 13, 1977.

"Bivalve Molluscan Resources and Problems along the U.S. Pacific Coast" by Dr. Ken Chew, Professor, University

of Washington College of Fisheries, Seattle, Washington, January 9, 1978.

"Field Experimental Studies of Benthic Invertebrates in Florida" by Dr. David Young, Head Chemical & Biological Branch, Naval Oceanographic Laboratory, January 10, 1978.

"Toxic and Sublethal Effects of Pentachlorophenol to Crustaceans" by Dr. Ranga Rao, Department of Biology, West Florida State University, January 24, 1978.

"Reminiscences on the Development of the Shrimp Fishery and Shrimp Biology on the Gulf Coast of the United States" by Dr. Gordon Gunter, Director Emeritus, Gulf Coast Research Laboratory, February 7, 1978.

"Seasonal Changes in Macrobenthic Communities off the Columbia River" by Dr. Michael Richardson, Naval Oceanographic Research and Development Activity, National Space Technology Laboratory, February 14, 1978.

"Developmental Plans for Gulf Islands National Seashore" by Mr. Noel J. Pachta, Assistant Park Superintendent, Gulf Islands National Seashore, February 28, 1978.

"Electron Microscopy in Aquatic Pathology" by Dr. William E. Hawkins, Department of Anatomy, University of South Alabama, March 14, 1978.

"Polymers for Energy, Environment and Humanitarian Concerns" by Dr. C. McCormick, Department of Polymer Sciences, University of Southern Mississippi, March 28, 1978.

"Oyster Culture in the State of Washington" by Ms. Katherine A. McGraw, Oyster Biology Section, Gulf Coast Research Laboratory, April 4, 1978.

"Diversity of Form and Colour in Gulf Coast Amphipod Crustaceans" by Dr. E. L. Bousfield, National Museum of Natural Science, Ottawa, Canada, April 11, 1978.

"Copepods: Both Near and Far" by Mr. John Steen, Ecology Section, Gulf Coast Research Laboratory, April 25, 1978.

"Fishery Product Inspection Perspective" by Mr. Spencer Garrett, Director, National Seafood Quality and Inspection Laboratory, May 9, 1978.

"Land Use and Population Patterns" by Mr. Claude Pittman, Gulf Regional Planning Commission, May 30, 1978.

"Successional Changes in Ichthyofauna of a New Artificial Reef" by Mr. Ron Lukens, Anadromous Fishes Section, Gulf Coast Research Laboratory, June 6, 1978.

"Coastal Zone Management Program" by Mr. J. E. Thomas, Director, Mississippi Marine Resources Council, June 20, 1978.

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EFFECTS OF 1973 FLOODWATERS ON PLANKTON POPULATIONS IN LOUISIANA AND MISSISSIPPI

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ABSTRACT Studies to assess the impact of floodwater diversion on plankton populations in coastal waters of Mississippi and Louisiana were conducted from 23 April 1973 through 13 July 1973. Fixed stations in Lake Pontchartrain, Lake Borgne and western Mississippi Sound were sampled once in April, twice in May and June, and once in July. Stations in Terrebonne Parish, Louisiana were visited once in May, June and July.

Data are presented on changes in the species composition of zooplankton subsequent to the opening of the Bonnet Carré and Morganza floodways. The hydrographic conditions at the time of sampling are discussed.

INTRODUCTION

The Bonnet Carré and Morganza floodways serve to divert floodwaters from the Mississippi River to the Gulf of Mexico (Figure 1). The Bonnet Carré Floodway, located 25 miles above New Orleans, empties floodwaters into Lake Pontchartrain. The Morganza Floodway, 280 miles above Head of Passes on the Mississippi River and operating in conjunction with the Atchafalaya Basin Floodway, carries floodwaters to the Gulf by way of the lower Atchafalaya River and Wax Lake Outlet. Severe flooding in the lower Mississippi River valley and prolonged periods of local rainfall necessitated the operation of the floodways in the spring of 1973.

Opening of the Bonnet Carré Floodway began on 8 April with all gates open by 11 April. The floodway remained fully open until 30 May with all gates closed by 11 June. Opening of the Morganza Floodway occurred on 17 April with varying numbers of bays open until 15 June when all bays were closed. Studies to assess the impact of floodwater diversion on plankton populations were begun subsequent to the opening of the two floodways. Data in this report include plankton samples collected from 23 April 1973 through 13 July 1973.

MATERIALS AND METHODS

Field Procedure

Daytime samples of surface plankton were taken from 23 April 1973 to 13 July 1973 at stations 1 through 16 (Figure 2). These stations were visited once in April, twice in May and June , and once in July. Stations 17 through 23 in Terrebonne Parish were visited once in May, June and July (Figure 3). A plankton net with a mouth opening of 12 inches and mesh aperature of 193 microns was pulled at a constant speed for an interval of 10 minutes. The samples were preserved in the field in a 5% solution of formalin.

Salinity and temperature of the surface water were measured when each sample was collected. Determinations of temperature and salinity were made with a Beckmen salinometer (Model RS5–3).

Laboratory Procedure

The volume of plankton (in ml) for each sample was determined by allowing the sample to settle in a graduated cylinder. Samples with settled volumes exceeding 5 ml were aliquoted with a Folsom plankton splitter. Samples with large numbers of the ctenophore *Mnemiopsis mccradyi*, or samples containing excessive debris, were examined in their entirety.

AREA DESCRIPTION

Areas affected by the diversion of floodwaters through the Bonnet Carré Floodway included Lakes Pontchartrain and Borgne and the western sector of Mississippi Sound. The eastern end of Lake Borgne and the western sector of Mississippi Sound were also influenced by runoff from the Pearl River system. Floodwaters from the Morganza Floodway affected portions of Terrebonne Parish. Eighteen collecting sites were established in the Bonnet Carré outlet area and seven in Terrebonne Parish. Station locations are shown in Figures 2 and 3. To facilitate discussion of data, stations were grouped by geographic location into five areas (Table 1). Discussion of hydrographic and biological data will be by these areas.

AREA I

Two stations were located in area I in eastern Lake Pontchartrain (Figure 2, Table 1).

Bottom types along the south shore of the lake from the Rigolets to Irish Bayou are predominantly clayey silt (Barrett 1976). Vegetation surrounding this part of the lake is brackish marsh comprised mainly of wiregrass (*Spartina*

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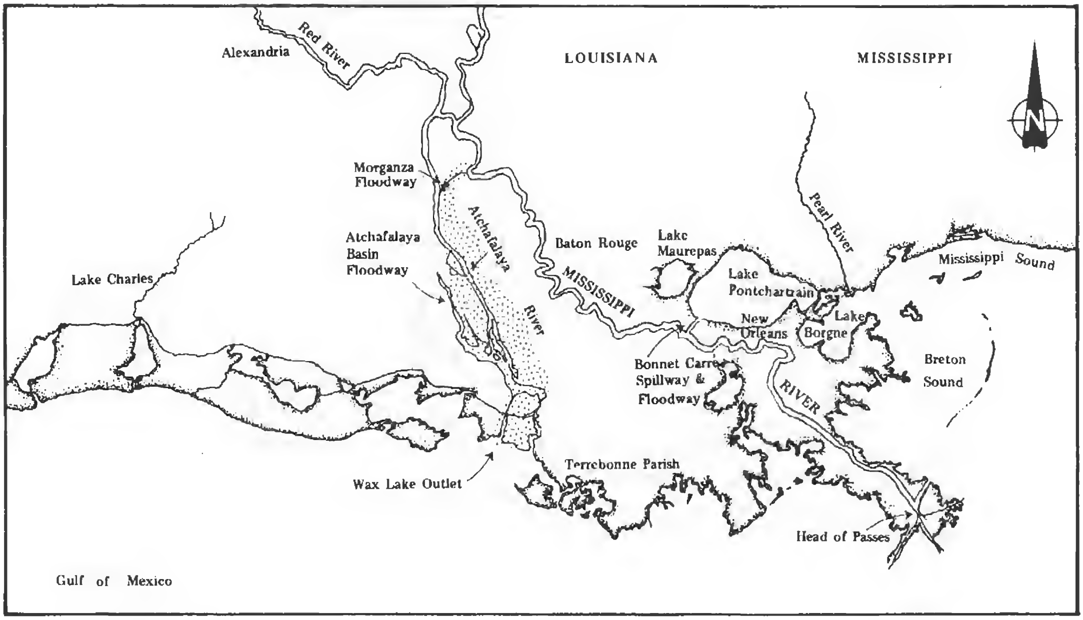

Figure 1. Location of the Bonnet Carré and Morganza floodways.

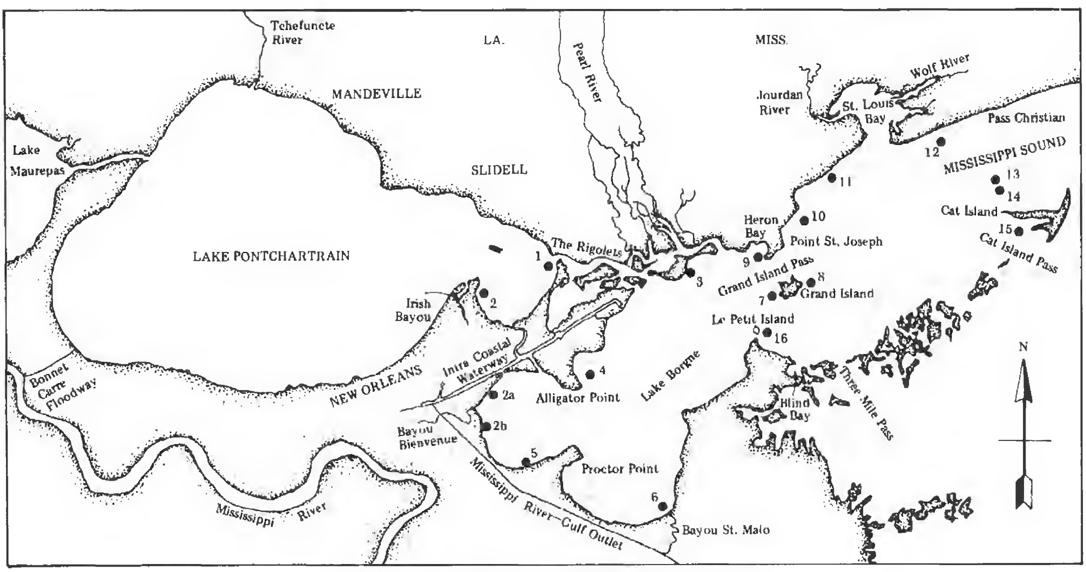

Figure 2. Location of stations 1 through 16.

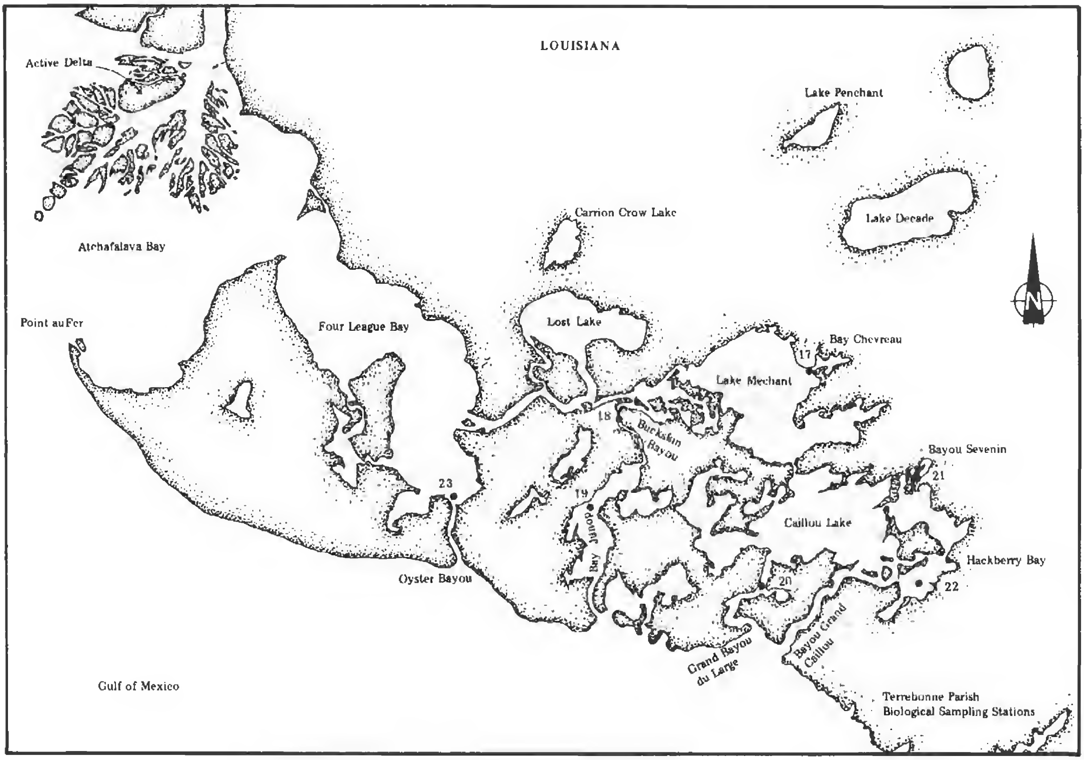

Figure 3. Location of stations 17 through 23 in Terrebonne Parish, Louisiana.

TABLE 1.

Station locations.

Area I	stations 1 and 2 in eastern Lake Pontchartrain
Area II	stations 2A, 2B, 4, 5 and 6 in western Lake Borgne
Area III	stations 3, 7, 8, 9, 10 and 16 in eastern Lake Borgne and extreme western sector of Mississippi Sound
Area IV	stations 11, 12, 13, 14 and 15 in western Mississippi Sound
Area V	stations 17, 18, 19, 20, 21, 22 and 23 in Terrebonne Parish

patens). Saltgrass (*Distichlis spicata*), oystergrass (*Spartina alterniflora*), coco (*Scirpus robustus*), black rush (*Juncus roemerianus*) and hogcane (*Spartina cynosuroides*) are also present (Chabreck 1972). Submerged vegetation is abundant near Irish Bayou, with tapegrass (*Vallisneria americana*) and widgeongrass (*Ruppia maritima*) both occurring. Tapegrass also exists along the north shore of the Rigolets. Water depths average 6 to 8 feet; near the entrance to the Rigolets the depth is 45 feet.

Hydrographic Data

Salinity. The hydrology of Lake Pontchartrain is greatly influenced by wind speed, wind direction and runoff of the rivers in the Pontchartrain basin; tidal fluctuations play a lesser role (Tarver and Savoie 1976). Darnell (1962) gives an average salinity of 5.0 ppt for the lake with fluctuations from 3.0 to 8.0 ppt as normal. He notes extremes of 1.2 and 18.6 ppt following heavy rainfalls and tropical Gulf storms, respectively. The studies of Stern et al. (1968), Barret et al. (1971a) and Tarver and Dugas (1973) support Darnell's data.

Surface salinities for stations in area I from April through July 1973 are shown in Table 2.

During and subsequent to the opening of the floodway, salinities dropped from 1.3 ppt to below 1.0 ppt for the sampling period. Tarver and Savoie (1976) also found salinities in the lake dropped during the 1973 opening of the floodway, decreasing from 1.5 ppt in April to 0.3 ppt in June, and rising in July to 7.4 ppt.

Salinities following the flood of 1973 were below average during the spring and summer of 1974, 1975 and 1976 (Tarver and Savoie 1976; U.S. Army Corps of Engineers 1974–1976).

TABLE 2.

Hydrographic data and settled volume of plankton for stations in area I.

Station	Parameter	April	[1]May	[2]May	[1]June	[2]June	July
1	ppt	1.3	0.0	0.2	0.3	0.2	0.0
2	ppt	0.3	0.0	0.0	0.0	0.2	0.3
1	°C	22.1	23.5	26.5	29.1	29.2	30.7
2	°C	22.0	22.2	24.9	27.2	29.6	30.0
1	ml	*1.0	*1.0	*1.0	1.0	30.0	*1.0
2	ml	*1.0	2.0	*1.0	*1.0	40.0	*1.0

*less than

Temperature. Surface temperatures in area I from April through July 1973 are shown in Table 2. Temperatures during this period were within the normal range for area I as reported by Tarver and Dugas (1973) and Tarver and Savoie (1976).

Biological Data

Settled Volume. The settled volume of plankton by station in area I is shown in Table 2. Eight of the twelve samples were under 1.0 ml in settled volume. The high settled volumes in the second June samples included copepods, cladocerans and large quantities of debris.

Zooplankton. A systematic list of zooplankton collected in area I is presented in Table 3. Published data on plankton in Lake Pontchartrain include: Wilson 1958; Suttkus et al. 1953–55; Darnell 1958, 1959, 1961, 1962; Bowman 1965; Stern et al. 1968; Stern and Stern 1969; Tarver and Dugas 1973 and Tarver and Savoie 1976.

Species diversity and abundance in our samples were low through May, increased greatly in June, and returned to low levels in July. Estuarine endemic species in area I included the copepods *Acartia tonsa*, *Eurytemora affinis*, *Eurytemora hirundoides*, *Halicyclops fosteri* and the meroplanktonic larvae of benthic invertebrates. Adventitious freshwater plankton occurred in the first May samples and in both June samples.

Rhithropanopeus harrisii zoeae were frequently occurring organisms, dominating the April and May samples. Zoeae of this species have not been reported from Lake Pontchartrain, although Darnell (1959) noted larvae that "may have been" *R. harrisii*, abundant and widespread in the lake during April and May at low salinities. Darnell (1959, 1961, 1962) reported large endemic populations of *R. harrisii* adults in the lake, and Cali (1972) found adults of this species common in the City Park pond system in New Orleans. Stern et al. (1968), Stern and Stern (1969) and Tarver and Dugas (1973) all reported decapod zoeae and/or larvae from the lake from May through July. Tarver and Savoie (1976) reported decapod larvae to be the primary component of plankton samples from their two stations in area I. The present study is the first report of *Uca* sp. larvae in the lake, although Darnell (1959) reported adult *Uca* sp.

Copepods were rare until June when species diversity and abundance increased dramatically. When copepods occurred in numbers, the species composition was unusual, the near absence of *A. tonsa* being most notable. All previous investigators reported *A. tonsa* to be the primary component of the plankton of the lake. During June 1973, copepods characteristic of fresh water (*Diaptomus*, *Cyclops* and *Mesocyclops*) were common to abundant. This is the first report of these three genera in Lake Pontchartrain. Estuarine endemic copepods occurring in the present study, *E. affinis*, *E. hirundoides* and *H. fosteri*, have been previously reported from the lake by Suttkus et al. (1953–55), Wilson (1958), Tarver and Dugas (1973) and Tarver and Savoie (1976).

Freshwater cladocerans, particularly species of *Diaphanosoma*, *Moina* and *Bosmina*, dominated the plankton during the second June samples. They were present in small numbers at the time of the first June samples. Suttkus et al. (1953–55), Stern et al. (1968) and Stern and Stern (1969) recorded limited numbers of *Bosmina longirostris*. Small numbers of estuarine-marine cladocerans, *Evadne* sp., *Podon* sp. and *Penilia avirostris*, were found by Tarver and Dugas (1973). In addition, Tarver and Dugas (1973) and Tarver and Savoie (1976) reported unidentified cladocerans from the lake. In the latter study, 99% of the unidentified cladocerans were taken in Lake Maurepas and at the mouth of the Tchefuncte River at salinities of 0.0 to 1.4 ppt. The present study is the first report of large numbers of freshwater cladocerans in eastern Lake Pontchartrain. These populations apparently represent washout from freshwater areas via the Mississippi and Pearl rivers. Large rivers such as the Mississippi normally have limited planktonic populations (Dotson 1966) but during high water, washout from quieter waters dramatically augments these populations. Bryan et al. (1974) reported cladocerans to be the most abundant zooplankters in the lower Atchafalaya basin. Cyclopoid copepods were the second most abundant organisms in their study. The freshwater cladocerans and copepods found in the present study are the same species as found by the above authors to be characteristic of freshwater areas in coastal Louisiana.

The meso-oligohaline amphipods *Gammarus mucronatus* and *Corophium louisianum* and the euryhaline species *Monoculoids edwardsii* were present in April. An unidentified species of *Corophium* occurred in June. Tarver and Dugas (1973) reported *G. mucronatus* and *Corophium* sp. from the lake. A limited number of isopods were noted during the present study. *Edotea* sp. has been reported by

Table 3.

Systematic list of zooplankton, area I.

Species	Stage	April	¹May	²May	¹June	²June	July
Pelecypoda	JUV*	3					
Modiolus demissus		4					
Polychaeta	LAR	4					
Ostracoda			1		1		1
Calanoida	COP					3,008	
Calanoida						768	
Acartia tonsa			1		25	64	19
Eurytemora hirundoides						128	
Eurytemora affinis		2	2		18	64	
Diaptomus sp.			5		96	5,888	
Cyclopoida	COP					192	
Cyclopoida						800	
Mesocyclops sp.					20	32	
Halicyclops fosteri					5		
Cyclops sp.					50	96	
Ergasilus sp.						60	
Argulus sp.				1	6	64	2
Cirripedia	NAU				1		1
Amphipoda		1			1		
Gammarus mucronatus		1					
Corophium louisianum		2					
Corophium sp.					5		
Monoculoides edwardsii		1					
Cassidinidea lunifrons			2				
Edotea sp.					1		
Mysidacea	ZOE					32	
Caridea	ZOE		8	2	73		2
Rhithropanopeus harrisii	ZOE	280	864	42	670		17
Uca sp.	ZOE				12		1
Callinectes sapidus	JUV			1	5	8	1
Diaphanosoma brachyurum					49	264,544	
Daphnia sp.			2		3		
Simocephalus vetulus			2		15		
Simocephalus exspinosus			2				
Moina sp.						171,520	
Moina micrura					160	224	
Bosmina coregoni						17,536	

TABLE 3 — Continued

Species	Stage	April	¹May	²May	¹June	²June	July
Bosmina longirostris					1	384	
Sida crystallina						64	
Moinodaphnia macleayii					10		
Insecta				P**			
Anisoptera				P			
Tendipes sp.				P			
Osteichthyes	LAR	42	5	12	167		68
Syngnathus sp.	JUV			1			
Najas guadalupensis					P		
Lemnaceae					P		
Lemna sp.			P	P	P	P	
Spirodela oligorhiza				P			
Spirodela sp.			P		P	P	
Wolffia columbiana			P	P	P	P	P
Wolffiella floridana			P	P	P		

*Abbreviations for stages of development in Tables 3, 5, 7, 9 and 11 are as follows:

COP	Copepodid	MED	Medusa
EGG	Eggs	MEG	Megalopa
HYD	Hydroid	NAU	Nauplius
IMM	Immature	NYM	Nymph
JUV	Juvenile	OPH	Ophiopluteus
LAR	Larva	PRO	Protozoea
LEP	Leptocephalus	PST	Postlarva
MAS	Mastigopus	ZOE	Zoea

**The letter "P" indicates occurrence in the sample without counts to show relative abundance.

Tarver and Dugas (1973) while this paper is the first published report of *Cassidinidea lunifrons* in Lake Pontchartrain.

Summary Area I. Previous studies of eastern Lake Pontchartrain suggest a planktonic community dominated by estuarine species with the meroplankton composed of the larval stages of *R. harrisii* and the holoplankton dominated by *A. tonsa*. The other major components were adventitious oligohaline and marine forms. Plankton samples in April and May 1973 were characteristically estuarine species dominated by the larvae of *R. harrisii*. In late June this community was replaced by freshwater-oligohaline species, primarily cladocerans and copepods. From May through June the presence of floating vascular plants such as duckweed (*Lemna* sp.) and watermeal (*Wolffia columbiana*) indicated the continuance of riverine washout.

AREA II

Four stations were located along the shores of Lake Borgne from Alligator Point to the mouth of Bayou St. Malo (Figure 2, Table 1). Stations 2A and 2B were added to the study in June.

Bottom sediments in the center of Lake Borgne are primarily clayey silt, with silty clay present in some areas along the shore (Barrett et al. 1971b). The marshes adjacent to Lake Borgne are brackish and dominated by wiregrass (*Spartina patens*); some saltgrass (*Distichlis spicata*) is also present (Chabreck 1972). Water depths in the lake range up to 9 feet (Barrett et al. 1971a).

Hydrographic Data

Salinity. Salinities in Lake Borgne at the time of construction of the Mississippi River–Gulf Outlet canal ranged from 1.5 to 6.0 ppt (el Sayed et al. 1961). After completion of the Gulf Outlet in 1968, salinities in Lake Borgne were substantially higher (personal communication, Johnny Tarver, Louisiana Wildlife and Fisheries Commission). With few exceptions, Tarver found the minimum salinity values for eastern Lake Borgne for April and May 1969–1972 exceeded the maximum value recorded by el Sayed et al. (1961). In April of 1970, Tarver recorded a high salinity of 17.7 ppt.

Surface salinities for stations in area II from April through July 1973 are shown in Table 4. With the exception of station 6 in April and station 5 in June, salinities were below 3.0 ppt until July. Stations 2A, 2B and 5 showed a rise in salinity as more saline conditions returned. Salinities at station 6 were highest in April. The geographic location and influence of the Mississippi River–Gulf Outlet canal may account for this.

Postflood data from Bayou Bienvenue and Alligator Point, supplied by personnel of the Louisiana Wildlife and Fisheries Commission, indicated that in a normal year, salinities increase during the period April through July. April salinities in 1974–75 ranged from 1.0 to 5.8 ppt while July salinities ranged from 4.4 to 17.0 ppt.

Surface temperatures for stations in area II from April through July 1973 are shown in Table 4. The lowest reading occurred in early May at station 5 and the highest occurred during the second June sampling at stations 4 and 6. In general, temperatures were within the ranges recorded by el Sayed et al. (1961) and the Louisiana Wildlife and Fisheries Commission.

Biological Data

Settled Volume. The settled volume of plankton by station in area II is shown in Table 4. No sample was received from station 2A for the first June sampling. Of the 23 samples collected, 19 had settled volumes under 1.0 ml.

Zooplankton. A systematic list of zooplankton collected in area II is found in Table 5. Papers describing the zooplankton of eastern Lake Borgne include el Sayed et al. (1961) and Cuzon du Rest (1963), who sampled during the construction of the Gulf Outlet canal and Gillespie (1971) who sampled after its completion.

Both el Sayed et al. (1961) and Cuzon du Rest (1963) found *Acartia tonsa* to be dominant in Lake Borgne. *Eurytemora hirundoides* was the second most common plankter. Cyclopoid copepods and cladocerans were also characteristic of these low-salinity (less than 3.0 ppt) waters. Decapod zoeae were reported, but in exceedingly low numbers (adult *Rhithropanopeus harrisii* were present). Gillespie (1971) found a typically estuarine plankton community with *A. tonsa* the principal species. The seasonal intrusion of marine species such as *Oncaea mediterranea* and *Undinula vulgaris* was noted. Freshwater organisms were conspicuously absent from her samples.

During the opening of the floodway in 1973, the plankton population of area II was composed of estuarine and freshwater species. Zoeae of *R. harrisii* were present in large numbers at each station. Limited numbers of *Uca* sp. and *Sesarma* sp. larvae were present from May through July. A few amphipods occurred. *Acartia tonsa* dominated the holoplankton, with large numbers of this estuarine species present in April, June and July. The freshwater component was dominated by ten species of cladocerans. Five of the six cladoceran genera found in the present study were reported by Chien (1969) in a study of the cladocerans of the Pearl River system. Some freshwater cyclopoids, such as *Diaptomus* sp. and *Cyclops* sp., were present mainly in June. Insects and/or floating plants were present at each sampling, indicating the continuing washout from fresh water. Representatives of the freshwater group Conchostraca were found during the

Table 4.

Hydrographic data and settled volume of plankton for stations in area II.

Area	Parameter	April	[1]May	[2]May	[1]June	[2]June	July
2A	ppt				0.2	0.2	2.6
2B	ppt				0.4	1.9	9.8
4	ppt	0.9	0.5	0.2	1.7	0.6	0.7
5	ppt	0.9	0.3	0.4	0.5	3.2	10.0
6	ppt	4.5	1.3	1.6	1.7	2.7	2.3
2A	°C				27.8	29.9	30.0
2B	°C				28.9	30.6	30.8
4	°C	24.3	25.1	26.1	29.1	32.6	32.9
5	°C	24.0	23.4	25.8	28.6	30.0	30.8
6	°C	24.4	23.8	27.2	29.4	32.6	32.2
2A	ml					*1.0	*1.0
2B	ml				*1.0	*1.0	*1.0
4	ml	*1.0	*1.0	*1.0	7.0	3.0	1.0
5	ml	*1.0	*1.0	*1.0	*1.0	*1.0	*1.0
6	ml	*1.0	*1.0	*1.0	*1.0	7.0	*1.0

*less than

Table 5.

Systematic list of zooplankton, area II.

Species	Stage	April	^{1}May	^{2}May	^{1}June	^{2}June	July
Coelenterata					20		
Ctenophora							
Beroe sp.							1
Pelecypoda	LAR*		10				
Tagelus divisus		1					
Tellina sp.		1					
Brachidontes recurvus		1					
Gastropoda	LAR	1			3		
Polychaeta		1				1	
Polychaeta	LAR					1	
Nereis sp.		1				2	
Arachnida						1	
Hydracarina						6	
Ostracoda					2	27	4
Copepoda	NAU					3	
Calanoida	NAU					515	
Calanoida	COP	12				69	2
Acartia tonsa		742	3	10	.185	312,813	363
Eurytemora affinis			1		1	8	
Diaptomus sp.		1			5	103	
Cyclops vernalis					10		
Cyclops sp.		1				20	
Ergasilus sp.						3,458	
Argulus sp.		1		5	14	22	9
Cirripedia	NAU	1			15	101	
Melita nitida			1				
Gammurus mucronatus				1			1
Corophium louisianum					1	16	
Corophium lacustre						1	
Corophium sp.						1	
Cerapus sp.		3		3			
Aegathoa oculata		2					
Mysidacea	ZOE				3		
Caridea	ZOE	58	61	19	38	10	24
Callinectes sapidus	JUV				8	4	4
Rhithropanopeus harrisii	ZOE	3,329	844	636	4,232	877	2295
R. harrisii	MEG						5
Uca sp.	ZOE			1	49	56	
Sesarma sp.	ZOE			1	75		1
Conchostraca						9	
Diaphanosoma brachyurum				2	145	3,151	
Daphnia sp.		2		1			
Moina micrura				1	2	901	
Moina affinis					3		

TABLE 5 – Continued

Species	Stage	April	^{1}May	^{2}May	^{1}June	^{2}June	July
Moina macrocopa				2			
Moina brachiata					110		
Moinodaphnia macleayii					1		
Simocephalus vetulus						24	
Bosmina coregoni						187	
Bosmina longirostris						142	
Insecta							P**
Hemiptera	JUV					P	
Corixidae	NYM			P			
Trichocorixa			P				
Hydropsyche	LAR						
Osteichthyes	EGG				5		
Osteichthyes	LAR	60	5	19	1,088	25	24
Anchoa mitchilli	JUV				13	1	
Anchoa mitchilli				1			
Syngnathus scovelli					2		
Syngnathus sp.	JUV	1					
Myrophis punctatus		1					
Atherinidae					107		
Gobiidae					14		
Hyporhamphus unifasciatus					1		
Spirodela sp.				P			
Lemna sp.					P		
Wolffia columbiana				P	P		P
Wolffiella floridana		P		P			
Coscinodiscus sp.		P	P	P			

*See Table 3
**See Table 3

second June sampling.

Summary of Area II. Both el Sayed et al. (1961) and Cuzon du Rest (1963), sampling during the construction of the Gulf Outlet canal, identified *A. tonsa* as the most abundant zooplankter, with freshwater copepods and cladocerans present. Cuzon du Rest (1963) found the plankton of eastern Lake Borgne characterized by fresh or brackish organisms. Gillespie (1971), sampling after completion of the Gulf Outlet, found the plankton of eastern Lake Borgne to consist almost entirely of the copepod *A. tonsa*; but the freshwater organisms found in the earlier studies were noticeably absent. She found plankton in the area to be primarily estuarine with the occasional intrusion of marine species. Plankton samples taken during the opening of the floodway

in 1973 more closely resembled those taken prior to completion of the Gulf Outlet with *A. tonsa* abundant and freshwater copepods and cladocerans common.

AREA III

Six stations were located in area III, one station near the mouth of Lake Borgne and five stations in the extreme western sector of Mississippi Sound (Figure 2, Table 1). No sample was taken from station 16 in Lake Borgne in April.

Bottom sediments in this area are primarily clayey silt or sandy silt. Submerged vegetation is sparse. Emergent vegetation in eastern Lake Borgne includes oystergrass (*Spartina alterniflora*), saltgrass (*Distichlis spicata*), black rush (*Juncus roemerianus*), and wiregrass (*Spartina patens*). *Juncus roemerianus*, and *Spartina alterniflora* dominate the marshes of the Mississippi coastline and are the predominant marsh type on Grand Island. Water depths are shallow and range from 2 to 10 feet with depths of 38 feet in Grand Island Pass.

Hydrographic Data

Salinity. Preflood surface salinities in area III from Three Mile Pass and Blind Bay, Louisiana, for the months of April through July 1968 ranged from 9.9 to 15.5 ppt and 7.5 to 14.3 ppt, respectively (Barrett et al. 1971a). Barrett et al. (1971a) note that salinities in this area are relatively low as a direct result of freshwater drainage from Lake Pontchartrain and Pearl River, and that salinities tend to correlate inversely with discharges from Pearl River. Hydrographic data collected in western Mississippi Sound near Point St. Joseph and Grand Island in 1968 record surface salinities ranging from 3.3 to 19.0 ppt from April through July. Christmas and Eleuterius (1973) consider this region of Mississippi Sound as part of the Pearl River estuarine system. They found a yearly mean surface salinity of 12.2 ppt in 1968. They also noted that salinities in this area were considerably lower than those in other Mississippi estuarine systems though seasonal trends were similar.

Surface salinities for stations in area III from April through July 1973 are shown in Table 6.

At the time of the April sampling, surface salinities in area III ranged from 0.0 to 4.2 ppt, the highest readings taken at stations 7 and 8 near Grand Island. With the exceptions of the first May sample and second June sample at station 16, when salinities were 1.2 ppt, surface salinities at stations in this area did not rise above 0.5 ppt from May through June. Salinities at all stations rose in July with high values of 6.8 and 8.4 ppt recorded at stations 8 and 10, respectively.

Isohalines (5.0 ppt increments) drawn for area III in the year following the 1973 flood were generously provided to the authors by Mr. Johnny Tarver of the Louisiana Wildlife and Fisheries Commission. All stations were within the 5.0 ppt isohaline in April and May. In June the 5.0 ppt isohaline shifted northward to include only stations 3, 9 and 10, with stations 7, 8 and 16 falling in the 10.0 ppt isohaline. By July, with the exception of station 16, all stations were again within the 5.0 ppt isohaline.

TABLE 6.

Hydrographic data and settled volume of plankton for stations in area III.

Station	Parameter	April	[1] May	[2] May	[1] June	[2] June	July
3	ppt	0.1	0.0	0.3	0.1	0.2	0.3
7	ppt	4.2	0.3	0.2	0.2	0.2	1.2
8	ppt	4.2	0.4	0.2	0.3	0.5	6.8
9	ppt	0.0	0.0	0.0	0.1	0.2	3.3
10	ppt	0.1	0.0	0.1	0.2	0.2	8.4
16	ppt		1.2	0.0	0.3	1.2	1.8
3	°C	23.7	21.9	24.7	27.7	29.9	32.0
7	°C	23.2	23.1	25.3	29.5	29.8	29.9
8	°C	23.8	24.7	26.1	29.1	30.8	30.3
9	°C	23.6	22.8	29.5	29.9	30.8	29.7
10	°C	23.5	25.4	27.2	29.9	32.0	30.3
16	°C		24.5	26.0	29.1	31.2	30.5
3	ml	*1.0	*1.0	*1.0	*1.0	*1.0	*1.0
7	ml	*1.0	*1.0	*1.0	*1.0	*1.0	*1.0
8	ml	*1.0	1.0	*1.0	*1.0	4.0	*1.0
9	ml	*1.0	*1.0	*1.0	2.0	1.0	*1.0
10	ml	1.0	*1.0	*1.0	4.0	*1.0	*1.0
16	ml		9.0	*1.0	*1.0	2.0	*1.0

*less than

Temperature. Surface temperatures for stations in area III from April through July 1973 are shown in Table 6.

Temperatures between stations showed the greatest monthly variations in May with differences of 3.5 and 4.8°C for the two sampling periods, respectively. The lowest reading was taken during the first May sampling effort at station 3 (21.9°C), with the highest readings (32.0°C) observed at station 10 in late June and station 3 in July.

Biological Data

Settled Volume. Settled volume of plankton by station in area III is shown in Table 6.

Settled volume of plankton was less than 1.0 ml in 27 of the 35 samples. The highest settled volume (9.0 ml) occurred at station 16 during the first May sampling and was associated with numerous larval fish and large numbers of the zoeal stage of the crab *Rhithropanopeus harrisii*.

Zooplankton. A systematic list of zooplankton collected in area III is found in Table 7. The authors were unable to find published data on the seasonal distribution and abundance of zooplankton in the eastern Lake Borgne—western Mississippi Sound area. Butler (1952), during and subsequent to the opening of the Bonnet Carré Floodway in 1950, made collections with a fine mesh net (No. 20) and

TABLE 7.

Systematic list of zooplankton, area III.

Species	Stage	April	1May	2May	1June	2June	July
Coelenterata	HYD*			3			
Pelecypoda	LAR	3	1		8	3	
Modiolus sp.		3					
Brachidontes recurvus		3					
Gastropoda	LAR			1	77	98	
Polychaeta				1			
Polychaeta	LAR	12					
Nereis sp.		6					
Oligochaeta			1				
Hirudinea						3	
Arachnida				1			
Hydracarina			3	2	4	15	2
Ostracoda		1			10	144	2
Copepoda	COP		3			88	
Calanoida						17	
Acartia tonsa		24	5	17	32	15,882	214
Eurytemora affinis				3	37	24	
Eurytemora hirundoides			1		25		
Eurytemora sp.						83	
Osphranticum labronectum				2			
Diaptomus sp.		2	2	1	32	135	
Cyclopoida		3	4	3	18	48	
Cyclops vernalis		2		1			
Cyclops sp.		10		2			16
Macrocyclops albidus					14		
Euterpina acutifrons							1
Ergasilus sp.						486	
Argulus sp.			4	5	14	83	15
Cirripedia	NAU					3	2
Cirripedia	IMM	3		26			
Balanus improvisus		3					
Melita nitida			1				
Gammarus mucronatus			1				
Corophium louisianum			1	1	1		
Hyalella azteca		1					
Isopoda					3		
Edotea sp.		4					
Caridea	ZOE	273	23	20	35	41	12
Palaemonetes pugio				1			
Palaemonetes vulgaris		2					
Penaeus aztecus	JUV	3					
Penaeus setiferus	JUV	4					

TABLE 7 – Continued

Species	Stage	April	1May	2May	1June	2June	July
Callianassa sp.	ZOE				19	10	
Callinectes sapidus	JUV			2	18	20	
Rhithropanopeus harrisii	ZOE	1,235	1,161	291	1,559	343	441
Rhithropanopeus harrisii	MEG				2	8	
Uca sp.	ZOE	10		1	198	262	
Sesarma sp.	ZOE			2	34	26	4
Leydigia quadrangularis					3		
Holopedium amazonicum			2	2	57	14	
Diaphanosoma brachyurum		3	1	16	579	630	
Sida crystallina		24	18			1	
Daphnia sp.		43	10	6	3	3	
Ceriodaphnia megalops		93		1	1		
Ceriodaphnia reticulata		9	1	2	6		
Moina micrura					5	37	
Moina affinis		7	1	1	1	6	
Moina macrocopa		7			1		
Simocephalus vetulus		7	42	5	80	1	
Simocephalus serrulatus		2					
Simocephalus exspinosus		2	31	3	3	1	
Bosmina sp.					1		
Bosmina coregoni						169	
Bosmina longirostris					1	15	
Eurycercus lamellatus		26	7	2	4		
Chydorus sphaericus					1		
Ilyocryptus spinifer					5	49	
Bosminopsis deitersi						14	
Moinodaphnia macleayii					51	9	
Insecta		1					40
Hemiptera	JUV		1	1	1	1	
Corixidae			1				
Corixidae	NYM				7		
Coleoptera			2				
Coleoptera	LAR					1	1
Berosus sp.	LAR		1				
Dytiscidae			1	1			
Ephemeroptera	LAR				2		
Diptera	LAR				1		
Tendipedidae	LAR					4	2

TABLE 7 – Continued

Species	Stage	April	[1]May	[2]May	[1]June	[2]June	July
Osteichthyes	EGG						2
Osteichthyes	LAR	30	106	10	575	29	40
Bothidae	LAR					1	
Anchoa mitchilli	JUV				20	6	
Micropogon undulatus	JUV	4					
Membras martinica		1					
Syngnathus scovelli					1		
Coscinodiscus sp.			P**	P	P	P	
Spirogyra sp.		P					
Najas guadalupensis						P	
Spirodela polyrhiza				P		P	
Lemna sp.				P		P	
Wolffia columbiana		P	P	P	P	P	P
Wolffia floridana		P	P	P	P	P	

*See Table 3
**See Table 3

enumerated the phytoplankton species collected over a five-month period. Zooplankters were not identified below the family level.

Estuarine-endemic species in area III plankton included the copepods *Eurytemora affinis, Eurytemora hirundoides* and *Acartia tonsa* and the meroplanktonic larvae of benthic invertebrates.

Plankton characteristic of freshwater lakes, ponds and rivers occurred in all months. Twenty-one species of cladocerans and several cyclopoid and diaptomid copepods were collected.

Zoeae of the xanthid crab *R. harrisii* dominated samples from April through the first June collections. These zoeae are seasonally abundant in the bays and bayous draining into Mississippi Sound and have been collected in fresh water in Simmons Bayou, Mississippi (personal communication, John Steen, Gulf Coast Research Laboratory). Adults of this species are common on the oyster reefs in Mississippi Sound.

With the exception of the euryhaline *A. tonsa*, copepods identified from area III were oligohaline or limnetic species. Representatives of the genus *Eurytemora* were present from May through June. Limnetic copepods were found in all months but were more numerous prior to the July samples. Species of *Diaptomus* and unidentified cyclopoids were the most abundant limnetic copepods. Small numbers of *Osphranticum labronectum, Cyclops vernalis,* and *Macrocyclops albidus* were taken. *Acartia tonsa* were abundant only in the second June samples. This species is adaptable to a wide range of temperature and salinity, and the near absence of this species through the first June samples suggests that the continuing flow of fresh water prevented the establishment of a population. Its importance in northern Gulf estuaries has been noted by Grice (1956), Cuzon du Rest (1963), Hopkins (1966), Gillespie (1971), and Perry and Christmas (1973).

Freshwater cladocerans were collected from April through June with species diversity greatest at the time of the first June samples. *Diaphanosoma brachyurum, Simocephalus vetulus* and *Bosmina coregoni* occurred in largest numbers.

Amphipods in area III samples were meso-oligohaline species (*Corophium louisianum, Melita nitida, Gammarus mucronatus*) with the exception of the freshwater-oligohaline *Hyallela azteca*.

Summary Area III. By combining a knowledge of the distribution of benthic adult invertebrates with preflood and postflood salinity data, the authors suggest that the endemic meroplankton in this area would, in all probability, largely be composed of the larval stages of brachyuran crabs and the zoeal larvae of caridean shrimp. *Acartia tonsa* would probably dominate the holoplankton. Assuming the above to be representative of the spring–summer plankton in area III, the changes in species composition brought about by the 1973 floodwaters are evident. Excluding the meroplanktonic larvae and juveniles of benthic invertebrates and juvenile fish, plankton collected in area III was characteristic of a freshwater-oligohaline fauna. The presence of insect larvae, mites, freshwater algae and vascular plants over the sampling period further demonstrates the influence of floodwaters.

AREA IV

Five stations were located in area IV in western Mississippi Sound in the St. Louis Bay estuarine system (Figure 2, Table 1).

Shoreline marshes are dominated by *Juncus roemerianus*. Beaches in the vicinity of station 12 are manmade and maintained for public use. Beds of shoalgrass *Halodule beaudetti* existed in the area of station 11 in 1968 but have since disappeared (personal communication, Lionel Eleuterius, Gulf Coast Research Laboratory). Bottom sediments are primarily muddy to fine sands. Extensive oyster reefs are located in this portion of Mississippi Sound.

Hydrographic Data

Salinity. Data for preflood and postflood salinities in area IV were furnished to the authors by personnel of the Fisheries Research and Development Section of the Gulf Coast Research Laboratory, Ocean Springs, Mississippi.

Mean surface salinities for selected stations in the western sector of Mississippi Sound for the year 1968 were 11.8 ppt in April, increasing to 20.5 ppt in July.

Surface salinities for stations in area IV from April through July 1973 are shown in Table 8.

Salinities were low at all stations in April and during the first May sampling period. Surface salinities at station 11 were below 1.0 ppt through June increasing to 14.2 ppt in July. Station 12 showed a gradual increase in salinity through July. Open water stations (13, 14 and 15), more closely adjacent to Gulf influence, exhibited greater fluctuations in salinity. Salinities at these stations generally were greater than salinities at shore stations through June. Salinities at all stations rose in July.

TABLE 8.

Hydrographic data and settled volume of plankton for stations in area IV.

Station	Parameter	April	[1]May	[2]May	[1]June	[2]June	July
11	ppt	0.1	0.2	0.1	0.4	0.3	14.2
12	ppt	0.1	0.0	1.3	1.6	8.6	19.2
13	ppt	0.5	0.0	16.6	5.7	10.6	16.8
14	ppt	1.2	0.0	19.5	6.3	12.3	16.7
15	ppt	2.2	0.7	12.1	6.3	18.6	21.5
11	°C	25.2	26.7	27.1	29.4	31.6	31.2
12	°C	25.1	25.8	25.9	28.5	29.6	30.9
13	°C	24.2	24.4	26.4	28.3	29.0	29.8
14	°C	25.4	24.0	26.5	28.7	28.9	29.8
15	°C	25.2	24.1	25.7	29.0	28.1	29.7
11	ml	*1.0	*1.0	*1.0	50.0	*1.0	120.0
12	ml	*1.0	*1.0	*1.0	1.0	*1.0	15.0
13	ml	*1.0	*1.0	*1.0	2.0	1.0	48.0
14	ml	*1.0	*1.0	*1.0	2.0	14.0	1.0
15	ml	*1.0	28.0	*1.0	*1.0	42.0	21.0

*less than

Postflood data for stations 12 and 15 were available for the years 1974, 1975 and 1976. Salinities in the vicinity of station 12 exhibited similar trends for the three years; low readings in April and May increasing through June and July. Postflood salinity means in 1974 in this area were similar to 1973 means and were slightly higher in 1975 and 1976. Readings for station 15, however, were consistently higher in postflood years.

The western end of Mississippi Sound is heavily influenced by drainage from the Pearl River and St. Louis Bay estuarine systems and depressed surface salinities are a natural occurrence for short periods of time. Circulation patterns in Mississippi Sound have recently been described by Eleuterius (1976). He noted that during periods of high river discharge the outflow from Pearl River passed through Grand Island Pass and turned southeast with some deflection to the northeast. Outflow from Jourdan and Wolf rivers empties into St. Louis Bay and follows the western shoreline of the Sound for some distance. These two systems operate to depress salinity levels in the western Sound during periods of peak river discharge.

Temperature. Surface temperatures for stations in area IV from April through July 1973 are shown in Table 8.

Temperatures between stations showed the greatest monthly variation (3.5°C) at the time of the second June samples. The lowest reading was taken at station 14 (24.0°C) in early May. The highest readings were 31.6°C and 31.2°C taken at station 11 in late June and July, respectively.

Biological Data

Settled Volume. Settled volume of zooplankton by station in area IV is shown in Table 8.

Settled volumes were less than 1.0 ml in 17 of the 30 samples. High settled volumes associated with the capture of large numbers of the cnidarian *Liriope tetraphylla* occurred in July at stations 11 and 13. Crustacean larvae and copepods contributed heavily to the settled volume of plankton at stations 11 and 15 in early and late June, respectively. The settled volume of 21.0 ml in July at station 15 was composed primarily of *L. tetraphylla* and calanoid copepods.

Zooplankton. A systematic list of zooplankton collected in area IV is found in Table 9. Little published information exists on the composition of zooplankton communities in western Mississippi Sound. Perry (1975) seasonally monitored the occurrence of *Callinectes* sp. zoeae and megalopae at stations near the mouth of St. Louis Bay and the western tip of Cat Island. Burke (1975) sampled several stations in the western Sound during an investigation of the occurrence and seasonality of planktonic cnidarians in Mississippi waters. Personnel of the Fisheres Research and Development Section, Gulf Coast Research Laboratory, collected monthly plankton samples in Cat Island Pass from October 1973 through September 1976, removing larval fish and larvae and postlarvae of penaeid shrimp and portunid crabs for identification.

The composition of zooplankton at stations in area IV in April and May 1973 consisted primarily of freshwater-oligohaline species and the larvae of benthic estuarine invertebrates. Estuarine-endemic holoplankters were *Acartia tonsa* and *Eurytemora affinis.* The meroplankton was composed of the zoeal stages of xanthid and ocypodid crabs, caridean shrimp and unidentified decapods. *Callinectes* sp. megalopae and a postlarval stage of *Penaeus aztecus* were found at station 15. Barnacle nauplii were present in small numbers. Freshwater copepods and cladocerans were present in both months with species diversity and numbers greatest during the April sampling period. Identified copepods included *Osphranticum labronectum* and *Macrocyclops albidus.* Twelve species of cladocerans were recorded, the most abundant being *Ceriodaphnia megalops.*

TABLE 9.

Systematic list of zooplankton, area IV.

Species	Stage	April	[1]May	[2]May	[1]June	[2]June	July
Liriope tetraphylla	MED*						8596
Bougainvillia carolinensis	MED						85
Eucheilota sp.	MED						8
Rhopalonema funerarium	MED						8
Phialidium languidum	MED						36
Eirene pyramidalis	MED						6
Eutima variabilis	MED						8
Siphonophora							2
Beroe ovata							P**
Mnemiopsis mccradyi		P					P
Pelecypoda	LAR				2	896	
Gastropoda	LAR	1			2	560	10
Polychaeta						4	2
Polychaeta	LAR					272	2
Hydracarina			1	1	1		
Ostracoda					130	363	
Copepoda	NAU				200	1,632	8
Copepoda	COP					8,029	
Acartia tonsa		2	190	58	1,550	215,084	199
Eurytemora affinis		2				4	
Eucalanus pileatus						96	25
Osphranticum labronectum		1					
Diaptomus sp.		2	2				
Labidocera aestiva					349	12,256	453
Centropages furcatus						640	10
Paracalanus parvus						1,280	
Cyclopoida		2		1	64	24	
Oithona brevicornis						1,112	
Macrocyclops albidus		3					
Corycaeus americanus						224	
Corycaeus amazonicus						160	
Ergasilus sp.						20	1
Euterpina acutifrons			8			2,960	
Argulus sp.		1		1	4	5	1
Cirripedia	NAU	2			20	8,288	9
Amphipoda						1	
Cerapus sp.		1					
Edotea montosa						4	
Aegathoa oculata				2	1	4	
Munna reynoldsi					1		
Decapoda	ZOE		6,544				
Caridea	ZOE	8	8	92	62	133	19
Penaeus aztecus	PST	1			1	4	
Acetes carolinae	PRO						9
Acetes carolinae	MAS				2		
Callianassa sp.	ZOE				64		
Upogebia affinis	ZOE				16	96	12
Callinectes sapidus	JUV				4	1	
Callinectes sp.	ZOE						23
Callinectes sp.	MEG			5	1	5	
Rhithropanopeus harrisii	ZOE	209	134	143	1,313	69	26
Rhithropanopeus harrisii	MEG	1	1			2	
Uca sp.	ZOE	1			833	242	37
Uca sp.	MEG					1	
Sesarma sp.	ZOE				31	1	40
Panopeus herbstii	ZOE						16
Panopeus herbstii	MEG					1	
Panopeus occidentalis	ZOE						4
Menippe mercenaria	ZOE						4
Holopedium amazonicum				2	4	2	
Diaphanosoma brachyurum		1			1,581	118	
Sida crystallina		6	1				
Daphnia sp.		35	4	3	2		
Ceriodaphnia megalops		51					
Ceriodaphnia reticulata		5		1			
Ceriodaphnia sp.		1					
Moina micrura					20	6	
Moina affinis		2					
Moina macrocopa						12	
Simocephalus vetulus		2			1		
Simocephalus serrulatus				1			
Simocephalus exspinosus		18		1			
Bosmina coregoni						2	
Bosmina longirostris					1		
Eurycercus lamellatus		1					

TABLE 9 – Continued

Species	Stage	April	[1]May	[2]May	[1]June	[2]June	July
Ilyocryptus spinifer				1	9	1	
Evadne sp.						736	
Penilia avirostris						96	
Podon sp.						32	
Insecta		2	8				
Corixidae				1			
Coleoptera		1					
Dytiscidae			1				
Odonata			1				
Bugula neretina					P		
Ophiuroidea	OPH						2
Oikopleura sp.					8	996	8
Branchiostoma sp.						1	
Sagitta enflata						32	1
Sagitta tenuis						228	18
Osteichthyes	EGG				20	732	22
Osteichthyes	LAR	52	74	14	175	21	3
Clupeiformes	LAR					4	
Elopidae	LEP	1					
Atherinidae	LAR					14	
Membras martinica		1					
Anchoa mitchilli	JUV					15	
Syngnathus sp.	JUV	1					
Syngnathus scovelli		1					
Coscinodiscus sp.				P	P	P	
Wolffia columbiana		P			P		
Wolffiella floridana		P	P		P		

*See Table 3
**See Table 3

By June, the species composition of plankton in area IV more closely resembled a coastal estuarine-marine fauna, though limnetic and oligohaline species continued to dominate samples from areas near freshwater runoff until July. Neritic copepods appearing in June included *Labidocera aestiva, Centropages furcatus, Eucalanus pileatus, Corycaeus americanus* and *Corycaeus amazonicus*. Among the many hydromedusae collected in July were *Liriope tetraphylla, Bougainvillia carolinensis, Phialidium languidum, Eirene pyramidalis* and *Eutima variabilis*. Three species of marine cladocerans (*Podon* sp., *Evadne* sp., *Penilia avirostris*) and two coastal marine chaetognaths (*Sagitta tenuis, Sagitta enflata*) were identified. The larvacean *Oikopleura* sp. was present in both months.

The composition of the meroplankton also changed markedly in June and July with the appearance of larval stages of *Upogebia affinis, Acetes carolinae, Callianassa* sp., *Panopeus herbstii, Panopeus occidentalis* and *Menippe mercenaria*.

Summary Area IV. Plankton samples from the mouth of St. Louis Bay and Cat Island Pass for the period May through September 1971 were examined by the junior author. The general composition of the plankton near the mouth of St. Louis Bay was similar for the five months, with the holoplankton dominated by *A. tonsa* and the meroplankton by the zoeae of caridean shrimp and the xanthid crab *R. harrisii*. Assuming the above to be representative of the plankton in this area during the warmer months, changes in species composition at stations 11 and 12 brought about by the floodwaters include the addition of numerous oligohaline and limnetic genera.

Plankton samples from Cat Island Pass in 1971 exhibited an estuarine-marine fauna. Holoplanktonic species included the neritic copepods *L. aestiva* and *C. furcatus* and the euryhaline *A. tonsa*. Hydrozoan medusae were present. Perry (1975) found *Callinectes* sp. zoeae in samples from Cat Island Pass in the spring and summer. In addition to the larval stages of *Callinectes* sp., the larvae of *Trachypenaeus* sp., *Penaeus* sp., *Lolliguncula brevis* and numerous sciaenid and clupeid fishes have been identified from surface tows in Cat Island Pass (personal communication, Ronald Herring, Fisheries Research and Development Section, Gulf Coast Research Laboratory). These studies support the author's assumption that the species composition of the plankton in the Cat Island Pass area is typically estuarine-marine, thus the effect of floodwaters at stations nearest the influence of Gulf Waters was most evident in April and May. Recovery of the system began in June with the return of estuarine-marine species.

AREA V

Seven stations were located in area V (Figure 3, Table 1). Stations 20 and 23 were in passes connecting shallow coastal lakes with the Gulf of Mexico. The remaining stations ranged as far as ten miles inland. Sampling in Terrebonne Parish was limited to a single trip in each of the following months: May, June and July. Station 23 was not visited in May.

Bottom sediments are primarily clayey silt (Barret et al. 1971b). Submerged vegetation is sparse, but some widgeongrass (*Ruppia maritima*) is present. The area is mainly saline marsh with oystergrass (*Spartina alterniflora*), saltgrass (*Distichlis spicata*) and wiregrass (*Spartina patens*) predominating (Chabreck 1972). Water depths are shallow in the lakes ranging from 2 to 5 feet. Depths in the passes vary from 17 to 20 feet.

Hydrographic Data

Salinity. Preflood surface salinities at the mouth of Oyster Bayou in June and July 1968 were 15.3 and 16.4 ppt,

respectively, with salinities from Bayou Grand Caillou ranging from 14.2 to 21.2 ppt from May through July 1969 (personal communication, Marilyn Gillespie, Louisiana Wildlife and Fisheries Commission). Under normal conditions, stations in area V would be expected to have some of the highest salinities of any of the areas studied. Salinity intrusion is occurring in Terrebonne Parish due to a multiplicity of factors: subsidence, the dredging of passes and the construction of canals.

Surface salinities for stations in area V from May through July 1973 are shown in Table 10.

Table 10.

Hydrographic data and settled volume of plankton for stations in area V.

Station	Parameter	May	June	July
17	ppt	0.3	0.1	0.0
18	ppt	0.1	0.1	0.0
19	ppt	0.3	3.3	2.0
20	ppt	0.7	3.8	7.9
21	ppt	1.5	3.2	0.3
22	ppt	2.5	6.1	1.4
23	ppt		0.0	0.0
17	°C	26.0	29.8	32.6
18	°C	26.0	29.1	31.2
19	°C	26.5	29.8	30.3
20	°C	28.0	30.1	30.4
21	°C	27.0	30.5	30.3
22	°C	28.0	30.7	31.3
23	°C		29.0	29.4
17	ml	*1.0	2.0	*1.0
18	ml	*1.0	*1.0	*1.0
19	ml	*1.0	2.0	*1.0
20	ml	*1.0	4.0	*1.0
21	ml	2.0	1.0	*1.0
22	ml	3.0	12.0	*1.0
23	ml		*1.0	*1.0

*less than

During the May sampling, salinities ranged from 0.1 to 2.5 ppt with the highest salinities recorded at the easternmost stations (21 and 22). Salinities were 0.1 ppt at the inland stations 17 and 18, and 0.0 ppt in Four League Bay (station 23) in June with salinities 3.2 or above at the remaining stations. In July, all salinities were 2.0 ppt or below with the exception of station 20. The pass at Grand Bayou du Large had a reading of 7.9 ppt, the highest salinity recorded in area V during the sampling period.

No postflood data were available on salinities from southwest Terrebonne parish.

Temperature. Surface temperatures for stations in area V for May through July 1973 are shown in Table 10. Temperatures appear to be within the normal range for the area.

Biological Data

Settled Volume. Settled volume of zooplankton by station in area V is shown in Table 10. Settled volume was less than 1.0 ml in 13 of the 20 samples. Large numbers of *Acartia tonsa* and *Uca* sp. zoeae contributed to the high settled volume at station 22 in June.

Zooplankton. A systematic list of zooplankton collected in area V is found in Table 11. Area data incorporating samples from Grand Pass des Ilettes, Bayou Grand Caillou, Grand Bayou du Large, Taylor's Bayou and Oyster Bayou in 1968–1969 were published in Gillespie (1971); however, the individual station data provided to the authors were not published. Her collections show the estuarine copepod *A. tonsa* and ctenophores to dominate the holoplankton. Other holoplankters such as *Labidocera aestiva* and *Eurytemora* sp. were occasionally present in small numbers. Marine calanoids, including species of *Eucalanus, Temora* and *Centropages*, entered the area in July although there was no distinct increase in salinity. The meroplankton was dominated by the larvae and postlarvae of decapods. Adult *Palaemonetes* sp. were collected in small numbers.

Table 11.

Systematic list of zooplankton, area V.

Species	Stage	May	June	July
Pelecypoda	LAR*	1		
Gastropoda	LAR	6	369	10
Polychaeta		1		
Polychaeta	LAR	64	32	
Nereis sp.			6	
Hydracarina		285	207	21
Arachnida				2
Ostracoda		142	5,415	5
Copepoda	NAU	64	18	
Copepoda	COP	3	145	3
Acartia tonsa		3,359	118,176	88
Eurytemora affinis		144	1	
Eurytemora hirundoides		8		
Eurytemora sp.		8		
Pseudodiaptomus cornutus		11		
Diaptomus sp.		70	51	5
Labidocera aestiva			5	
Harpacticoida			1	
Euterpina acutifrons		8	221	
Cyclopoida		12	105	
Cyclops sp.		89	36	
Ergasilus sp.		23	444	
Halicyclops fosteri		5		
Argulus sp.		37	100	19
Cirripedia	NAU	196	2,128	
Corophium sp.		7		
Corophium lacustre			14	
Corophium louisianum				3

TABLE 11 – Continued

Species	Stage	May	June	July
Gammarus mucronatus				3
Melita nitida			1	
Cerapus sp.		2	2	
Isopoda				15
Muna reynoldsi			1	
Edotea sp.		34		
Caridea	ZOE	464	230	70
Palaemonetes pugio		3		
Macrobrachium ohione				1
Callinectes sapidus	JUV	7	28	2
Rhithropanopeus harrisii	ZOE	2,147	2,707	544
Rhithropanopeus harrisii	MEG	6	1	
Uca sp.	ZOE	1,563	28,346	34
Uca sp.	MEG		11	
Sesarma sp.	ZOE	18	96	18
Penaeus aztecus	PST	13	1	
Callianassa sp.	ZOE	72		
Upogebia affinis	ZOE	8		
Diaphanosoma brachyurum		27	54	
Moinodaphnia macleayii			2	
Ilyocryptus spinifer		29	15	3
Sida crystallina		8		
Simocephalus vetulus		16	2	
Simocephalus exspinosus		7	3	
Moina micrura			2	
Moina affinis				2
Moina macrocopa		8		
Ceriodaphnia megalops		2	1	
Bosmina coregoni		2	89	
Bosmina longirostris			5	
Insecta		1		5
Tendipedidae	LAR			1
Trichoptera	LAR		1	
Osteichthyes	LAR	307	136	17
Anchoa mitchilli	LAR	2	1	
Anchoa mitchilli		2		
Adenia xenica		3		
Coscinodiscus sp.			P**	
Wolffia columbiana		P		
Wolffiella floridana		P	P	
Myriophyllum sp.				P
Najas sp.				P
Lemna sp.				P

*See Table 3
**See Table 3

Estuarine species dominated the May, June and July samples following the 1973 opening of the Morganza Floodway. *Acartia tonsa* was the most abundant holoplankter. The meroplankton was composed primarily of the zoeal stages of *Rhithropanopeus harrisii* and *Uca* sp. Numerous freshwater species were collected; however, none were present in large numbers. Members of the order Hydracarina were common as well as the freshwater copepods *Diaptomus* sp. and *Cyclops* sp. Twelve species of freshwater cladocerans were noted, with *Ilyocryptus spinifer, Diaphanosoma brachyurum* and *Simocephalus vetulus* the more numerous. Freshwater plants including duckweed (*Wolffiella floridana*) and water meal (*Wolffia columbiana*) occurred. Species diversity and abundance dropped in July.

Summary of Area V. Gillespie's data show the spring and summer plankton populations in area V to be dominated by the copepod *A. tonsa* and the meroplanktonic larvae of benthic invertebrates, with marine organisms entering the area in July. During the 1973 opening of the Morganza Floodway, freshwater copepods and cladocerans augmented the normal planktonic fauna. The usual July intrusion of marine species was not observed.

GENERAL SUMMARY

The 1973 opening of the Bonnet Carré and Morganza floodways had a dramatic but short-term impact on plankton populations in adjacent coastal waters. Plankton populations in the estuarine waters of Mississippi and Louisiana are generally endemic assemblages, with the holoplankton dominated by *Acartia tonsa* and the meroplankton by the larvae of benthic crustaceans. Higher salinity portions of these estuarine areas normally show an increase in marine forms as salinities rise through the summer. During and subsequent to the floodway openings, however, the normal estuarine populations were augmented by the addition of numerous freshwater-oligohaline species. As salinities returned to normal levels, these forms were eliminated.

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An Improved, Conceptually Simple Technique for Estimating the Productivity of Marsh Vascular Flora

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AN IMPROVED, CONCEPTUALLY SIMPLE TECHNIQUE FOR ESTIMATING THE PRODUCTIVITY OF MARSH VASCULAR FLORA

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ABSTRACT The estimation of the net primary productivity of marsh communities with a periodic maximum–minimum (PMM) technique has certain advantages over the long used maximum–minimum standing stock technique, but still retains the same conceptual simplicity. The final productivity estimate with PMM is based on the entire data set rather than just two points. Direct statistical comparisons between any two communities can be made. An estimate of the productivity by minor species in the community can also be made. The periodic model permits statistical comparisons about other variables in community growth such as the timing of the maximum standing crop. With certain assumptions, productivity estimates which account for the loss of live plant material during the growing season can be made without the tremendous amount of effort and time required by the Wiegert–Evans technique. Despite the increased utility the PMM technique requires no additional field effort.

INTRODUCTION

The productivity of coastal tidal marshes is a useful way to compare the potential productivity of estuaries (Turner 1977). Estimation techniques for tidal marsh productivity range from conceptually simple techniques such as the standard maximum–minimum (max–min) standing crop technique to techniques that measure the disappearance of material from plots in addition to the increase in living plant material (Wiegert and Evans 1964). Each technique has certain advantages over other techniques. The Wiegert–Evans technique may provide a better estimate of plant productivity, but requires more time and effort than the standard max–min technique. Determination of the best technique depends greatly on the amount of effort available, the community to be studied, and the eventual use of the data. The ideal technique must account for (1) the variation of plant density throughout the study marsh;(2) the inherent variation between sampling dates;(3) the death of new plant growth during the growing season; (4) the productivity of minor plant species in the community; and (5) loss of new plant growth through herbivory.

The following is a method for estimating marsh plant productivity using the conceptual simplicity of the max–min technique, but allows the researcher to account for these other variables in his estimate. The use of a statistical model improves the reliability of the productivity estimate and provides a valid mathematical model through which other tests and comprisons can be made. These advantages are added without substantially increasing the amount of effort required for the max–min technique. The technique also has the advantage of allowing straight-forward statistical comparisons between any two studies regardless of when or where they are made. The periodic model has widespread application and has provided a good fit for many other biological phenomena (Odum and Smalley 1959; Buzas 1969; Brown and Taylor 1971; Hackney et al. 1976).

METHOD

The periodic regression model differs from the usual general regression model only in the functional form of the independent variable. The usual general one-term linear regression model is:

$$y_i = \alpha + \beta x_i + \epsilon_i \qquad i = 1, \ldots, n.$$

The corresponding one-term periodic model considers the trigonometric functions of x_i as

$$y_i = \alpha_0 + \alpha_1 \cos(cx_i) + \beta_1 \sin(cx_i) + e_i \qquad (1)$$

where

y_i = dependent variable
α_0 = constant parameter
α_1, β_1 = coefficients of the harmonic function of x_i
c = $2\pi/n$
x_i = i th independent variable
e_i = error.

Note that a pair of trigonometric terms constitute a single harmonic term. In most ecological problems the independent variable x_i is time, each x_i representing a unit of time such as months, $i = 1, 2, \ldots, 12$. The dependent variable y_i could be temperature, salinity, number of organisms, etc.

The semi-amplitude of the curve described in equation (1) would be

$$A = \hat{\alpha}_1^2 + \hat{\beta}_1^2$$

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and the phase angle estimated by

$$\mathrm{Tan}\,(\hat{\theta}) = |\hat{\beta}_1/\hat{\alpha}_1| \ .$$

The number of terms in the model is determined in the same manner as choosing the number of terms in any regression model. The goal is to find a model that adequately describes the data, and also has biological validity. As in polynomial regression, it is possible to add enough terms to the periodic model to achieve an exact fit. The addition of harmonic terms should depend upon the biological interpretation of the model. If only the diel cycle is known to effect a given phenomenon yet five harmonics are required to explain the data, then the model is probably incorrect. Other factors, not necessarily periodic, might need to be considered in the model. The periodic model usually provides an excellent fit for productivity data (Bliss 1970; Hackney and Hackney 1977). This technique allows the use of stratified sampling collection procedures which are less destructive to marshes than simple random collection techniques and less time consuming. Since the fitted curve used samples collected over the entire marsh, the final resulting max–min values reflect the variation in plant density within the marsh as well as the inherent error between samples. The standard max–min procedure only reflects the variation of the highest and lowest biomass estimates. Estimation of the productivity of minor species can be made using the same periodic curve with these same conceptual advantages overcoming the usual patchiness of minor plant species distribution, essentially integrating this highly variable component into a smooth curve. If data are available on the death rate of plants within the community, a productivity estimate may be obtained that, like the Wiegert–Evans technique, includes productivity lost by the early death of plants. In many cases these data are available with little increase in effort.

Examples

The data used in the following examples were collected in a Mississippi tidal marsh located on the western side of St. Louis Bay, Mississippi. The vegetation on this marsh was described by Gabriel and de la Cruz (1974).

The increase of above-ground vascular plant biomass in marshes usually follows a periodic type of curve as does the increase in the below-ground portions of these plants (de la Cruz and Hackney 1977). An examination of the means of each collection plotted against time will provide visual proof of whether the periodic model is appropriate. In the following examples five 0.25 m^2 samples were collected on each date. The first example demonstrates what factors are used to determine the validity of the model and the difference between a productivity estimate made through the periodic max–min technique and an estimate with the standard max–min technique. The second example provides a mathematically sound method of estimating the contribution by minor plant species in the community, while the third example compares two models that produced similar quantities of biomass, but produced them at different times. The last example shows how a better productivity estimate can be obtained if information on the death rate of the plants is known.

One disadvantage of the traditional max–min technique is that it uses only two values from the entire year's collection, the highest and lowest standing crop of living plant material. With this technique the community in Figure 1 had a productivity of 481 $g/m^2/yr$. A periodic curve fitted to all of the data points also provides a maximum and minimum value, but these values are based on the entire data set and the variability of all samples. There were 372 $g/m^2/yr$ of vascular plant production estimated by this technique. The periodic model of the *Juncus* community in Figure 1 is

$$Y = 770.9 - 88.7 \sin(ct_i) - 162.9 \cos(ct_i)$$

where $c = 2\pi/12$ and $t_i = 1, \ldots, 12$ based on 40 observations. The r^2 was 0.493 with a significant F of 18.0 which indicates a significant ($\alpha = 0.05$) periodic component and a significant r^2 in the data set. The test of a significant periodic component is the most important factor when deciding whether to accept the use of the periodic model. If this component were nonsignificant a model based just on the overall mean would be more appropriate. More information on the actual testing of periodic models is provided by Hackney and Hackney (1977). The variability of plant distribution within a marsh plant community may cause what seems to be low r^2 values. This variability affects the r^2 most if a random stratified sampling scheme is used. If one is willing to accept the assumption that the

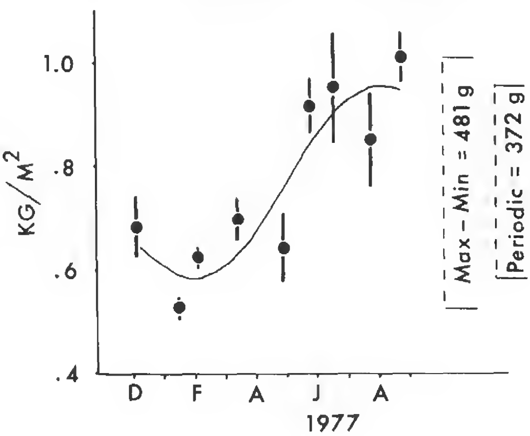

Figure 1. Monthly changes of live biomass in a *Juncus* community. Vertical lines represent ± one standard error. The smooth curve is predicted from the periodic model. Estimates derived by the simple max–min technique and the periodic model are compared.

increase in plant biomass follows a periodic pattern then a random stratified sampling procedure may be used, which does not disturb the marsh, and is not as time consuming as the simple random collection technique.

Perhaps the most difficult component to isolate in a marsh plant community is the contribution of the minor species to the productivity of the community. This may be done through the development of a periodic model for the increase of living plant biomass for the entire community, and a separate model for the dominant plant species, in this example *Juncus roemerianus* (Figure 2). Subtraction of the two productivity estimates yields an estimate of the contribution by the minor plant species in the community, which in this case was 56 g/m^2/yr.

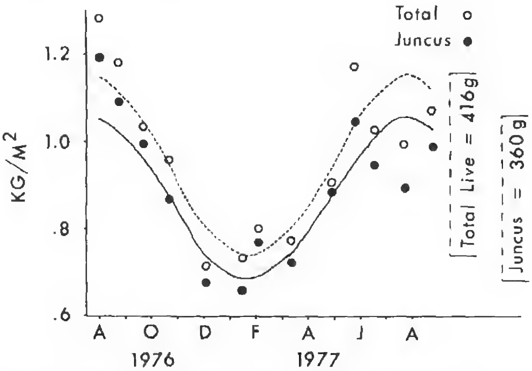

Figure 2. Periodic models of the total live plant biomass and the total live *Juncus* in a control community. The mean of each monthly collection is provided for comparison. The difference between the productivity estimates is an estimate of the productivity of the minor species in the community.

Another useful aspect of this technique is the ability to test whether the growth (productivity) of two communities is the same. Using the standard max–min technique one has two numbers to compare and no way to make a statement about any statistically significant differences between the two communities. In the following example, two *Spartina cynosuroides* communities were compared the second year following a burn in one community (Figure 3). A comparison of the two periodic models indicated that there was no significant difference ($\alpha = 0.05$) in the amount of live biomass produced, but that the peak production was reached earlier in the burned community. This type of information is not available directly from other estimation techniques. Interpretation of the analysis of variance (ANOVA) output necessary to make these decisions is provided by Hackney and Hackney (1977).

Despite the reliability realized through the use of this periodic max–min technique there are still certain components of plant productivity that are not considered. Hopkinson et al. (in press) emphasized the need for any

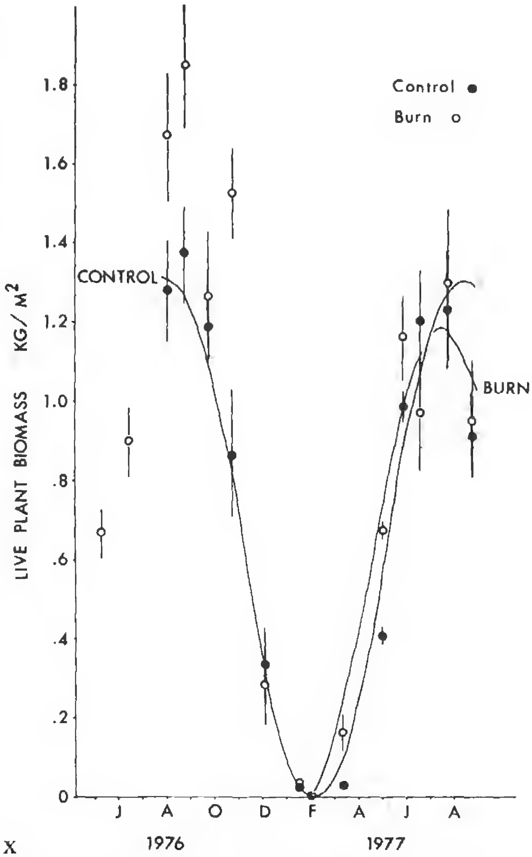

Figure 3. Periodic models of the natural and burned *Spartina cynosuroides* community. Individual points represent the mean ± one standard error.

productivity estimate to account for the loss of dead plant material from a community. This is most important if the above-ground portions of the plant do not die during the winter, such as *J. roemerianus* along the Gulf coast or if the turnover rate is very high. To integrate this component into a periodic max–min estimate one can produce a mathematical model based on the accumulation of dead material during the growing season. It is necessary to be sure that this dead material was produced during the growing season. To do this an area can be cut at the beginning of the growing season and samples collected from this area each month. In the case of plants that die each winter, cutting does not seem to affect the accumulation of dead material during the growing season. The only potential effect is the lack of shading that may be produced by the previous year's dead standing biomass. In the case of perennial plants (*Juncus*, etc.) which stay green all year this practice may have some effect. The addition of this component to the productivity

estimate may require the addition of a significant amount of field work to the study. In the following example this was not a factor since the intent was to estimate the productivity of a *Juncus* community following a fire. A general model that combined a periodic component with an asymptotic exponential function provided a good fit for the increase of dead material in the burned *Juncus* community. Models besides the asymptotic exponential would be adequate provided that they adequately represent the data. The predicted model of the live biomass, dead biomass and the combined model (Figure 4) illustrates the need to account for this dead component. In this particular case 115 g/m^2 was added to the annual productivity of this community by accounting for the loss of new living material during the growing season.

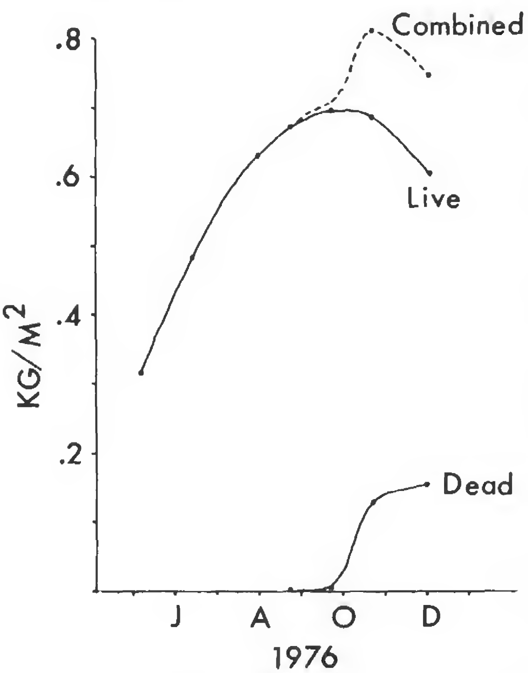

Figure 4. Periodic model of the living plant biomass, model of the accumulation of dead plant material and the combined value of a burned *Juncus* community.

DISCUSSION

The measurement of net primary productivity in any marsh system is necessary to completely understand the energetics of that system. Techniques that measure other factors besides changes of live biomass (Wiegert and Evans 1964) may be useful if the additional time and effort are available. It is unlikely that the literature on marsh plant productivity will ever achieve the uniformity that Turner (1976) and Kirby and Gosselink (1976) feel is necessary when other researchers consider the max–min technique adequate (de la Cruz 1978). The periodic max–min technique (PMM) could provide uniform estimates of marsh plant productivity since most of the published data could easily be recalculated using this technique. The technique still possesses the conceptual simplicity which de la Cruz (1978) believed desirable. With only a small amount of increased effort other factors such as the instantaneous loss rate, productivity of minor species in the community, and various sampling problems can be accommodated with the PMM technique. Kirby and Gosselink (1976) fitted a polynomial function to the changes of live and dead material they found in a salt marsh. These data could have been easily fitted to a periodic model. The biological interpretation of a polynomial model is not usually apparent, while the interpretation of a periodic model is usually straight forward. For example, a fourth-degree polynomial is equivalent to a single harmonic model. Interpreting the meaning of raising an independent variable, e.g., time, to the fourth power is more difficult than explaining a single cycle over a specified interval. Also direct estimates of amplitude and phase are available. Periodic models may also reveal differences between communities via periodic regression analysis (Hackney and Hackney 1977).

The calculation of the actual primary productivity of marsh plants is difficult. In the past we have separated the productivity of the aerial portion of the plant (leaves and stems) from the productivity of the roots and rhizomes. This below-ground productivity may be as high as the above-ground productivity (de la Cruz and Hackney 1977). More recently Hopkinson et al. (in press) have shown that productivity estimates that do not consider the short-term turnover rate may greatly underestimate the primary productivity of some marsh plant species. The estimation of the loss of newly produced plant material (instantaneous loss rate) in a marsh community has many associated problems (Hopkinson et al., in press). A relatively simple method of estimating this loss rate is shown in Figure 4. This technique would not be appropriate for plants with a rapid turnover rate and would not be as good an estimate as that obtained by the paired plot technique of Hopkinson et al. (in press). Both techniques require the disturbance of an area by the researcher that could affect the final results. The effect of clipping all vegetation from an area and then following the accumulation of dead material during the growing season may not affect the resultant estimate any more than the variables introduced by the Wiegert–Evans technique.

Hopkinson et al. (in press) suggested that the max–min technique underestimated the actual productivity of marshes because it does not account for the loss of newly produced organic matter. An additional criticism of the standard max–min technique is that it provides a poor estimate of the actual increase of living plant biomass because it is based on only two points, each of which is subject to the inherent

variability found in any natural system (Figure 1). The periodic max–min technique provides an estimate that is based on every sample collected during the study. Thus, the primary productivity estimate obtained through the periodic max–min technique may be higher or lower than the standard max–min technique, but is far more reliable. If the model which predicts the loss of new plant growth is added to the periodic model, an estimate is produced that is higher than either of the max–min estimates and comparable to the Wiegert–Evans technique.

Since the periodic max–min technique is easy to use, conceptually simple, and satisfies some of the criticisms of other techniques, it is suggested as the best general method available to estimate the net primary productivity in marsh communities.

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Food of the Red Drum, *Sciaenops ocellata,* from Mississippi Sound

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FOOD OF THE RED DRUM, *SCIAENOPS OCELLATA*, FROM MISSISSIPPI SOUND[1]

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ABSTRACT Examined digestive tracts of the red drum in Mississippi Sound contained mostly decapod crustaceans. Crustaceans accounted for 34 of 59 encountered taxa, more than reported from any other region. Nevertheless, the general diet for 104 fish with food contents out of the 107 examined is similar to that reported for red drum in several other studies from other areas. In addition to crustaceans, fishes followed by polychaetes occurred as the most important items (in 99, 43, and 15% of the drum with food, respectively). Blue crabs occurred in even more drum than the frequently encountered penaeid shrimps. Other commercial species were negligible in the diet. Sixteen large drum from Georgia beaches were also examined; unlike those from Mississippi, many of these contained echinoderms, but not polychaetes or penaeids. We suggest that the red drum's migrations may be regulated by optimal abundance of specific types of dietary organisms.

INTRODUCTION

The red drum, *Sciaenops ocellata*, also commonly called redfish or channel bass, is an important sportsfish in Mississippi coastal waters. Consequently, in order to appreciate that fish's relationship with other organisms in the region, we investigated its specific diet in Mississippi and examined the relative extent of its predation on commercial shrimps and crabs. In the northern Gulf of Mexico, the drum typically feeds (1) in shallow marsh areas rooting about with its head lowered and its tail occasionally out of the water; (2) in relatively deep inshore water in depressions behind sandbars or channels adjacent to mud- or grassflats (Yokel 1966), or (3) for large adults, in Gulf water, usually near shore, but occasionally several kilometers offshore. The amount of drum caught from a locality appears directly related to the locality's amount of estuarine area (Yokel 1966).

MATERIALS AND METHODS

A total of 107 red drum, 104 with food in their stomachs or intestines, was collected between May 1976 and August 1977 by hook and line or gill net and placed on ice or frozen until examined. The fish came from a variety of habitats: (1) near barrier islands, (2) open water of Mississippi Sound, and (3) Davis Bayou, Biloxi Bay, and other sites adjacent to marsh grass. After taking standard lengths (SL) of fish, we either immediately identified food items or preserved them in 10% formalin. Twenty-two additional adult drum were examined from Sapelo Island, Georgia, and treated identically.

RESULTS

Fifty-nine different taxa plus remains of several more unidentified ones occurred in the red drum (Table 1). Most of these were crustaceans and all but one drum with food contained at least one crustacean (99%). Even with the extensive variety in crustaceans, few of which had been reported previously as drum food, blue crabs and penaeid shrimps occurred most frequently. The commonly encountered penaeid and palaemonid shrimps, however, occurred in a smaller percentage of fish longer than 50 cm than of shorter fish. On the other hand, the percentages of drum with blue crabs, the stomatopod *Squilla empusa*, and some other items were greater in the larger fish (Table 2).

Fishes, occurring in 43% of the drum, constituted the second most abundant item. These occurred more commonly in larger fish (Table 2); 65% of those drum over 50 cm had fish in their stomachs compared with 43 and 30% in the two smaller groups. Polychaetes also contributed to the diet, but appeared less important in fish over 50 cm. Other items were rare in the drum examined from Mississippi.

Some seasonality in diets was apparent (Table 3). As examples, some relatively uncommon food items, annelids, echinoderms, and a bryzoan (probably ingested passively while feeding on another organism), occurred only during winter and spring, whereas the stomatopod occurred exclusively during spring and fall. On the other hand, when considering the prevalent blue crabs and penaeid shrimps, we found the percentage of crabs was greater in spring and summer and that of the shrimps in winter and fall.

The contents of 16 relatively large drum from Sapelo Island, Georgia, are listed in Table 4.

DISCUSSION

Even though we list many more specific food items than other reports on the red drum's food, our findings agree generally. Pearson (1929), Gunter (1945), Kemp (1949), Miles (1949;1950), and Knapp (1950) from Texas; Fontenot and Rogillio (1970) and Boothby and Avault (1971) from Louisiana; and Yokel (1966) from Florida all provided data on over 100 examined drum. Contents from numerous juvenile drum have also been recorded from Texas by Miles

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TABLE 1.

Percentage of occurrence of organisms and other material obtained from the stomachs and intestines of 104 red drum in Mississippi Sound.

Food Items	Occurrence (%)	Food Items	Occurrence (%)
Polychaetes		*Pinnixa* sp.	1.0
Chaetopterus variopedatus tube	1.0	*Portunus gibbesi*	5.8
Glycera americana	10.6	*Processa* cf. *hemphilli*	6.7
Nereis succinea	3.8	*Rhithropanopeus harrisi*	1.9
Unidentifiable polychaete	1.9	*Sicyonia brevirostris*	1.9
Stomatopod		*Sicyonia dorsalis*	1.0
Squilla empusa	8.7	*Speocarcinus lobatus*	1.9
Amphipods		*Tozeuma carolinensis*	1.0
Ampelisca abdita	1.0	*Trachypenaeus similis*	2.9
Unidentifiable ampithoid	2.9	*Uca longisignalis*	2.9
Decapods		Unidentifiable goneplacid	3.8
Alpheus heterochaelis	5.8	*Upogebia affinis*	1.0
Alpheus normanni	2.9	**Ectoproct**	
Callinectes remains	6.7	*Bugula neritina*	4.8
Callinectes sapidus	17.3	**Holothuroid**	
Callinectes similis	36.5	*Thyonacta mexicana*	1.0
Chasmocarcinus mississippiensis	1.0	**Echinoid**	
		Mellita quinquiesperforata	3.8
Emerita talpoida	1.0	**Fishes**	
Euceramus praelongus	1.0	*Achirus lineatus*	1.0
Hepatus epheliticus	5.8	*Anchoa mitchilli*	5.8
Hexapanopeus angustifrons	5.8	*Brevoortia patronus*	1.0
Hippolyte pleuracantha	3.8	*Cyprinodon variegatus*	2.9
Leiolambrus nitidus	1.0	*Diplectrum* sp.	1.0
Lepidopa bennedicti	1.9	*Gobiosoma bosci*	1.9
Neopanope texana	27.9	*Micropogonias undulatus*	1.0
Ovalipes floridanus	2.9	*Mugil cephalus*	1.0
Palaemonetes pugio	8.7	*Myrophis punctatus*	8.7
Palaemonetes vulgaris	5.8	*Paralichthys lethostigma*	1.0
Penaeus aztecus	3.8	*Selene vomer*	1.0
Penaeus duorarum	16.3	*Symphurus plagiusa*	4.8
Penaeus remains	6.7	Unidentifiable blenniid	1.0
Penaeus setiferus	11.5	Unidentifiable fish remains	23.1
Periclimenes longicaudatus	1.0	Unidentifiable goby	4.8
Persephona punctata aquilonaris	3.8	**Algae**	2.9
Pinnixa chacei	1.9	**Detritus**	1.9

TABLE 2.

Percentage of occurrence of organism-groups in the digestive tracts of 104 red drum by length-groups from Mississippi Sound.

Food Items	Length of Fish in mm SL: 190–349 43 fish	350–499 35 fish	500–780 26 fish	Total (%)
Polychaetes	18.6	17.1	7.7	15.4
Bryzoan	2.3	5.7	7.7	4.8
Echinoderms	0.0	2.9	11.5	3.8
Stomatopod	2.3	2.9	26.9	8.7
Amphipods	7.0	2.9	0.0	3.8
Penaeid shrimps	44.2	42.9	30.8	40.4
Palaemonid shrimps	18.6	20.0	0.0	14.4
Callinectes crabs	48.8	62.9	53.8	54.8
Other decapods	37.2	65.7	80.8	57.7
Fishes	30.2	42.9	65.4	43.3
Algae	2.3	5.7	0.0	2.9
Detritus	4.7	0.0	0.0	1.9

TABLE 3.

Percentage of occurrence of organism-groups in the digestive tracts of 104 red drum by season from Mississippi Sound.

Food Items	Season: Winter 30 fish	Spring 34 fish	Summer 26 fish	Fall 14 fish	Total (%)
Polychaetes	33.3	14.7	0.0	7.1	15.4
Bryzoan	13.3	2.9	0.0	0.0	4.8
Echinoderms	3.3	8.8	0.0	0.0	3.8
Stomatopod	0.0	17.6	0.0	21.4	8.7
Amphipods	0.0	0.0	3.8	14.3	3.8
Penaeid shrimps	53.3	23.5	30.8	71.4	40.4
Palaemonid shrimps	23.3	8.8	15.4	7.1	14.4
Callinectes crabs	36.7	70.6	65.4	35.7	54.8
Other decapods	86.7	70.6	19.2	35.7	57.7
Fishes	56.7	41.2	26.9	50.0	43.3
Algae	6.7	0.0	0.0	7.1	2.9
Detritus	3.3	0.0	3.8	0.0	1.9

TABLE 4.

Percentage of occurrence of organisms from the digestive tracts of 16 specimens of red drum, 43 to 102 cm long, caught from June through August 1970 at different beach localities of Sapelo Island, Georgia.

Food Items	Occurrence (%)
Molluscs	
Barnea truncata	6.3
Petricola pholadiformis	6.3
Sinum perspectivum	6.3
Crustaceans	
Callinectes sapidus	31.3
Callinectes similis	12.5
Hepatus epheliticus	6.3
Ovalipes ocellatus	12.5
Pagurus longicarpus	6.3
Portunus gibbesi	12.5
Echinoderms	
Mellita quinquiesperforata	18.8
Sclerodactyla briareus	37.5
Fishes	
Fundulus majalis	6.3
Leiostomus xanthurus	6.3
Menticirrhus americanus	6.3
Mugil cephalus	18.8
Opsanus tau	6.3
Trachinotus carolinus	6.3
Trinectes maculatus	6.3
Unidentified fish	6.3

(1950) and from Louisiana by Bass and Avault (1975). Other less extensive data on food items were reported by Reid (1955), Reid et al. (1956), Simmons (1957), Breuer (1957), Darnell (1958), Inglis (1959), Springer and Woodburn (1960), and Simmons and Breuer (1962). Bascially, crustaceans and fishes provided most of the reported food items for the red drum. Components fluctuated some because of various factors. Shrimps and crabs comprised the most frequently encounted crustaceans, and the frequencies of those organisms varied considerably. Gunter (1945) implied that crabs were eaten more in bay waters, whereas shrimp dominated the diet in and near Gulf water; Pearson (1929) considered the blue crab most important as food when small or in molting condition; Miles (1950) thought fishes and crabs became important when shrimp became scarce; Yokel (1966) found shrimp most important in South Florida from July to September, but crabs most important during the other periods; Yokel also found the red drum to eat proportionally more crabs as it grew larger, with xanthid crabs gaining in importance and portunids losing in importance; and Boothby and Avault (1971) considered crabs and shrimp of equal importance in the diet.

Fishes also composed an important part of the red drum's food. Boothby and Avault (1971) found fish in 75% of the stomachs constituting 35% of the food's volume in a southeastern Louisiana marsh. All other studies found fish of less importance to drum except that of Inglis (1959) who examined small drum and possibly Breuer (1957) and Simmons (1957) who did not provide data. In most areas, fish appear to become less important to large drum even though often making up a significant part of the drum's diet. Reid et al. (1956) recorded 23 menhaden in one drum. On the other hand, Pearson (1929) suggested small mullet provide the best bait for large drum, and shrimp provide it for small ones. If crabs are to be used as bait, Simmons and Breuer (1962) said the legs should be removed and the body halved. Most feeding takes place in early morning and late evening.

Our study on food contents in Mississippi Sound shows several trends. Three of these are: (1) that polychaetes, especially *Glycera americana*, are fairly important components, being most commonly seen in fish smaller than 50 cm; (2) that echinoderms are eaten by large fish; and (3) that many different decapods, at least 34 in number, provide food. Crabs occurred in more stomachs than shrimps, but both groups, especially commercial species, constitute heavily preyed-on organisms. Actually, the lesser blue crab, *Callinectes similis*, not previously reported from the red drum (except possibly by Kemp [1949] as *C. danae* [see Williams 1974]), occurred in more fish than *C. sapidus* (37 versus 17%).

Knowledge about the habits of the decapods listed in Table 1 reveals that the red drum feeds in sandy to muddy bottoms from both shallow and moderately deep water. A few dietary organisms such as *Chasmocarcinus mississippiensis*, a commensal crab, have been observed in the locality infrequently. Most species, however, make up common components of the different ecosystems in and adjacent to Mississippi Sound.

Large drum feeding near the high energy beaches of Sapelo Island, Georgia, (Table 4) reveal crustaceans and fishes as important dietary components. They, however, also feed heavily on echinoderms. Additionally, molluscs occurred, but not polychaetes. As in Mississippi, the variety of both decapods and fishes is extensive.

Grassbeds also constitute an important community in which drum, especially preadults, feed. Specific animals act as indicators of fish feeding in that habitat. Some are *Neopanope texana*, *Hippolyte pleuracantha*, and *Penaeus duorarum*. Other animals support feeding activities in other areas. As examples, *Rhithropanopeus harrisi* shows feeding from upper-bay, low-salinity areas; *Uca longisignalis* from shallow mudflats; and *Emerita talpoida*, *Pinnixa chacei*, and *Mellita quinquiesperforata* from open sandy beaches.

The seasonality of the drum's diet probably primarily reflects availability of the specific organisms, but some selectivity also appears evident. Fall is when shrimp, especially white shrimp, are abundant and when 71% of the drum had penaeid shrimp as food contents. On the other hand, many shrimp should also be available during spring and summer. During those two seasons, blue crabs seem to

have greater priority as food. When blue crabs were not prevalent during winter, various crabs and a few other miscellaneous decapods prevailed both as food contents and as common organisms in the habitat.

Whereas the menhaden and mullet are the most common dietary fishes in some areas, those items were not encountered commonly in our food samples. In fact, the most frequently identified fish were the speckled worm eel and bay anchovy. Many fish could not be identified because of their digested state.

Conspicuous by their absence were gastropods, bivalves, mysids, and copepods. These, especially the latter two, both of which are crustaceans, probably occur commonly in fingerling drum from Mississippi Sound.

Even though the diet of red drum from some other geographic regions consisted largely of individuals comprising one taxon, we did not encounter similar findings. We, however, did find 18% of the drum with a single food source and, of those, ten had a blue crab, six had a penaeid shrimp, two had the mud crab *Neopanope texana*, and one had a fish. About half of those drum came from the northern part of the Sound near marsh grass and the remainder came from near the barrier islands.

We did not sample small red drum; however, a few other workers have. Bass and Avault (1975), in the most extensive report, found that fish less than 30 mm fed primarily on zooplankton. As the fish reached 26 mm long, the frequency of calanoid copepods dropped off and that of mysids increased. Little difference occurred between food contents encountered during day or night until the drum reached 65 mm when consumption of shrimp prevailed during the day contrasting with that of fish at night. Polychaetes and amphipods also accounted for considerable food. Evidence based on fewer samples by Hildebrand and Schroeder (1928), Miles (1950), Springer and Woodburn (1960), and Odum and Heald (1972) essentially corroborated the above findings. Inglis (1959), who examined fish 30 to 100 mm long from Texas, however, found about 80% contained fish, 10% contained amphipods, and fewer contained a variety of other organisms.

Migration of red drum might be dictated by the abundance of specific food items. In other words, the drum might continually migrate in a relatively consistent pattern in order to optimize specific rich food sources. Thus, fish would exploit different areas seasonally. The data from Sapelo Island, Georgia, reveal that large fish fed heavily during the summer on the five-lunuled sand dollar *Mellita quinquiesperforata* and the sea cucumber *Sclerodactyla briareus* near the high energy sandy beaches. We also recovered similar items in a few fishes during May from Mississippi, and Thomas McIlwain (personal communication) found numerous individuals of the sea catfish, *Arius felis;* the sea pansy, *Renilla muelleri;* and *M. quinquiesperforata* in six 9- to 10-kg fish caught off Horn Island in September 1966. Possibly the fish that ate echinoderms and associated infauna were migrating to other regions with relatively underutilized crustaceans, but taking advantage of different underutilized subsurface organisms on the way. These items are probably important to the overall diet of red drum and to its natural history.

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Amphilochidae (Crustacea: Amphipoda) from the Western Gulf of Mexico and Caribbean Sea

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AMPHILOCHIDAE (CRUSTACEA: AMPHIPODA) FROM THE WESTERN GULF OF MEXICO AND CARIBBEAN SEA

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ABSTRACT Two new species of *Amphilochus, Amphilochus casahoya* and *Amphilochus delacaya*, and one new species of *Gitanopsis, Gitanopsis laguna*, are described. Relationships within these genera, particularly *Amphilochus*, are difficult to determine. The new species, however, are similar to some eastern Pacific forms. One known species, *Amphilochus neapolitanus* is also reported as occurring in both the Gulf and Caribbean.

INTRODUCTION

The Amphilochidae are a group of ubiquitous amphipods which are often overlooked because of their small size (2–4 mm). Only one species, *Gitanopsis tortugae* Shoemaker, 1933, has been reported from the Gulf of Mexico (Shoemaker 1933). J. L. Barnard (1969) erroneously reported *Cyclotelson purpureum* Potts, 1915, from the Gulf of Mexico. *C. purpureum* was described by Potts (1915) from the Torres Straits near Murray Island in the Coral Sea.

ILLUSTRATIONS

Figures follow the format established by J. L. Barnard (1970). Capital letters on the figures designate a specific structure. Lower case letters preceding the capital letter identifies a specific individual. Lower case letters or numbers following the capital letter modifies the description of the part: B = labrum (upper lip); C = coxa; G = labium (lower lip); H = head; L = palp; M = mandible; N = gnathopod; O = outer plate or outer ramus; P = pereopod; Q = mandibular molar; S = maxilliped; T = telson; U = uropod; X = maxilla; Z = mandibular incisor; a = anterior; b = without; h = holotype; l = left; r = right; w = palm; x = medial; and y = article.

Amphilochidae

Diagnosis. Accessory flagellum absent; coxa 1 reduced, partly hidden by a following coxa.

Amphilochus Bate, 1862

Diagnosis. Mandibular molar small, nontriturative or with few ridges; gnathopod 2 large, subchelate.

Key to *Amphilochus*

1a. Mandible nontriturative but armed with a spine; anterior edge of article 6, gnathopod 2 without submarginal spines. . . . . *A. neapolitanus*

1b. Mandible reduced but with ridges; gnathopod 2, article 6 anterior edge with 1-4 submarginal spines 2

2a. Gnathopod 2, article 6 with 1-2 submarginal spines. . . . . *Amphilochus casahoya*

2b. Gnathopod 2, article 6 with 4 marginal spines . . . . *Amphilochus delacaya*

Amphilochus neapolitanus Della Valle, 1893

Stebbing 1906:150; Chevreaux and Fage 1925: 112–113, figs. 106–108; J. L. Barnard 1962:126, fig. 3

Diagnosis. Eyes small, round to slightly oval; antenna 1 reaching beyond antenna 2; mandible nontriturative with a single spine; outer face of gnathopod 2, article 6 without submarginal spines.

Material. Texas stations: NT:NMFS–106A, 29°30′N 95°0′W; NT:NMFS–13A, 29°0′N 95°30′W. Other material was taken at Ascension Bay, Mexico, and Nicchehabin reef, Allen Point, and Santa Maria point on Cozumel Island, Mexico.

Distribution. Circumtropical and warm-temperate.

Amphilochus casahoya, new species (Figures 1 and 2)

Description. Female 3.15 mm. Head and body normal for genus, eyes circular with black center bordered with numerous opaque ommatidia. Antenna 1: Article 2 of peduncle 1.3 times as long as article 1, and 3 times as long as article 3; flagellum with 8 articles, distoventral corner of each article with 1-2 elongate, flattened setae; accessory flagellum uniarticulate, subequal in length to first article of flagellum. Antenna 2: Article 5 of peduncle 1.3 times as long as article 4, articles 4 and 5 with distal spines, article 5 with medial row of 4 short spines; flagellum with 11 articles. Upper lip: Normal for genus. Mandible: Molar conical, right molar with 3 elongate spinelike ridges, left similar to right but lacking any oversized ridges; accessory blades 11-12; incisor produced forward and medially, distal part V-shaped, toothed, palp with 3 articles of length ratios 12:46:57, otherwise normal for genus. Maxilla 2: Inner plate with medial row of submarginal spines; outer plate longer than inner, with 4 terminal spines. Maxilliped: Article 3 of palp

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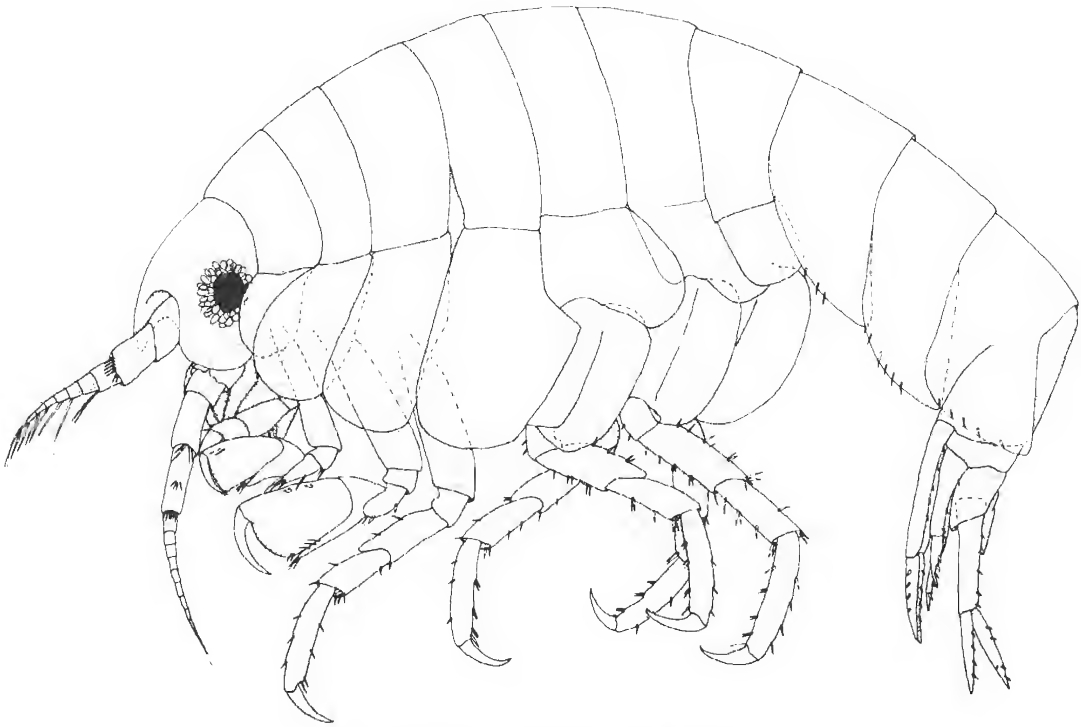

Figure 1. *Amphilochus casahoya*, n. sp., female 3.15 mm.

produced medially, with a number of complex spines and 4 short, rounded teeth, otherwise normal for genus. Gnathopod 1: Coxa suboval, partly hidden by following coxa; article 2 elongate; article 4 with 1 medial spin on posterior margin and 6 distal spines; article 5 with spinose posterior lobe; article 6 with 1 anterodistal, 2 mediofacial spines and serrate, transverse palm lined with 6 slender spines and defined by 2 stout spines; inner margin of dactyl serrate. Gnathopod 2: Article 4 with stout mediomarginal and 2 distal spines; article 5 with elongate posterior lobe reaching edge of palm, outer margin of lobe with 3 basal spines, distal part spinose; article 6 distally expanded with 1-2 submarginal spines on outer face, palm transverse, serrate, lined with slender spines, corner defined by 2 stout spines; inner margin of dactyl serrate, distally attenuate. Pereopod 3: Coxa longer than wide; articles poorly spinose; anterior margin of article 4 with 2 spines, posterodistal corner with 1; article 5 with 1 spine on either margin, distally spinose; article 6 with 3 anteromarginal and 4 posteromarginal spines; dactyl attenuate. Pereopod 4: Coxa large, quadrate, posterior margin excavate; margins of articles with short spines; posterior spine formula of article 6–2,2,2,1; anterior margin of article 6 with 3 spines; dactyl attenuate. Pereopod 5: Coxa with rounded posterior lobe; article 2 expanded; articles spinose; anterior spine formula of article 6–2,2,2,1; dactyl attenuate. Pereopod 6: Coxa like 5 but smaller; longer than preceding pereopods; anterior spine formula of article 6–1,2,2,2,1; posterior margin with 4 spines; dactyl attenuate. Pereopod 7: Coxa subquadrate; pereopod otherwise like pereopod 6. Epimera: Ventral margin of epimeron 1 with 3 spines; epimeron 2 with 6 ventral spines and epimeron 3 with 5 ventral spines; posterior margins unproduced. Uropod 1: Peduncle elongate, inner margin with 3 slender spines, outer margin with 5 short spines; inner ramus with 4 inner marginal spines; ramal spines inserted in incisions on margins. Uropod 2: Peduncle with 1 distal spine on inner margin and 4 outer marginal spines; inner ramus with 3 inner marginal and 4 outer marginal spines and setulose basal margins; outer ramus 0.6 times as long as inner; inner margin setulose, outer margin with 2 stout, slightly hooked spines and 1 normal distal spine, tip somewhat attenuate; uropod shorter than either 1 or 3. Uropod 3: Peduncle longer than uropod 2; outer margin with 5 spines; rami lanceolate, inner margin of inner ramus with 4 spines and outer margin with 1 spine; outer margin of outer ramus with 4 spines; opposing margins of rami setulose. Telson: normal for genus.

Male. unknown.

Type. Holotype, USNM 170756, female 3.15 mm; paratype female 2.96 mm, USNM 170757.

Type–locality. 7.5 fm reef, Texas, 26°50'N 95°40'W.

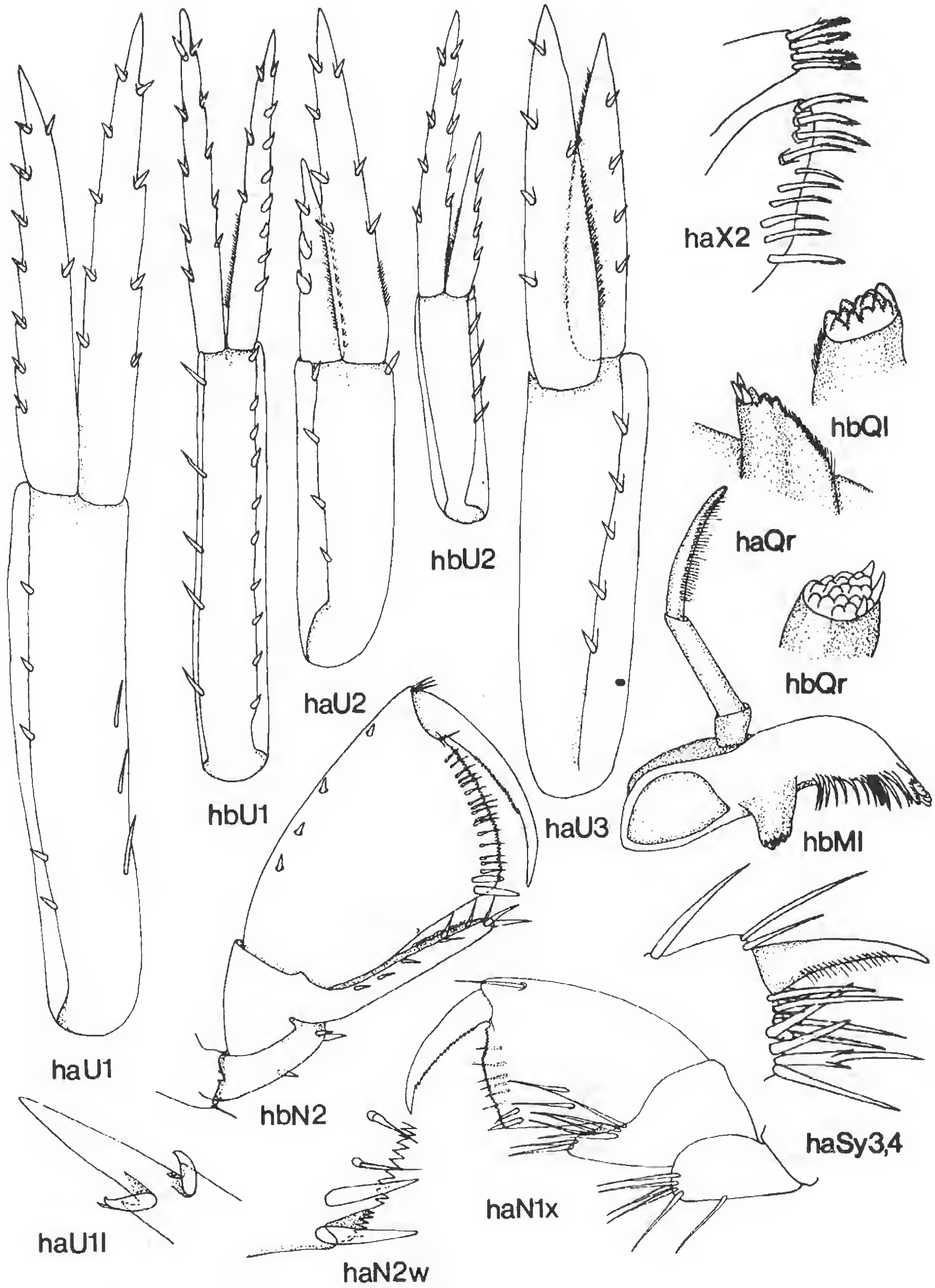

Figure 2. *Amphilochus casahoya*, n. sp., female 3.15 mm = ha; *Amphilochus delacaya*, n. sp., female 2.55 mm = hb.

Material examined. Specimens from the type–locality and the jetty complex at Port Isabel, Texas. Size range: 2-3.5 mm.

Distribution. Gulf of Mexico, offshore waters from intertidal to 15 m.

Relationships. *Amphilochus casahoya* is most closely related to *Amphilochus delacaya*, n. sp., which is also described in this paper. *Amphilochus casahoya* differs chiefly in having only 1-2 submarginal spines on article 6 of gnathopod 2 rather than 4 as in *A. delacaya*. Uropods of *A. casahoya* are less spinous than in *A. delacaya*.

This species appears very close to the Hawaiian species, *A. likelike* J. L. Barnard, 1970 and *A. menehune* J. L. Barnard, 1970. These two species as well as *A. casahoya* are also similar to *Gitanopsis vilordes* J. L. Barnard, 1962, in many aspects, except in the structure of the mandible.

Relationships among the amphilochiids are, in general, poorly known. They are a difficult group with which to work as they require extensive dissection for even generic determinations. The lack of detailed descriptions and figures of known species also makes it difficult to demonstrate relationships among the members of this genus.

Ecological information. This species was taken from a Serpulid reef (known as 7.5 fm reef) some 20 km off the south Texas coast and the intertidal margins of rock jetties of Port Isabel, Texas.

Amphilochus delacaya, new species (Figure 2)

Diagnosis. Female 2.55. Like *A. casahoya* in all but the following:

Outer margin of article 6 on gnathopod 2 with 4 submarginal spines; Peduncle of uropod 1 with 5 slender inner marginal and 10 stout outer marginal spines; inner ramus of uropod 1 with 5 spines on both inner and outer margins; subequal outer ramus with inner margin basally setulose and 3 distal spines, outer margin with 8 stout curved spines; inner ramus of uropod 2 armed with 4 inner marginal and 5 outer marginal spines, outer ramus with 4 outer marginal spines.

Types. Holotype, USNM 170754, female 2.55 mm.; paratype series of 4 specimens, USNM 170755.

Type–locality. Isla de Lobos Reef, Vera Cruz, Mexico.

Material examined. The types plus other specimens from the type–locality.

Distribution. Gulf of Mexico, Mexican coast, 5 m depth.

Relationships. Most closely related to *Amphilochus casahoya*; refer to discussion under that species.

Ecological information. This species was found only on coral reefs in the groove and buttress zones.

Gitanopsis Sars, 1895

Diagnosis. Mandibular molar large, triturative, gnathopod 2 small, subchelate.

Gitanopsis laguna, new species (Figures 3 and 4)

Description. Female, 2.37 mm. Head and body normal for genus, eyes round. Antenna 1: Length ratio of peduncle articles 1,2,3–20:23:14; flagellum with 6 articles. Antenna 2: Articles 4 and 5 subequal in length; flagellum with 5 articles; antenna 2, 0.8 times the length of antenna 1. Upper lip: Bilobed, longer than wide. Mandible: Molar produced, triturative, upper margin with elongate spines; 8 accessory blades on right and 9 on left mandible, blades increasing in width distally; left incisor typical, upper edge folded over and inward in an inverted "V"; right incisor normal and toothed; palp with 3 articles of length ratios 24:43:58, article 3 lanceolate, ventral margin spiculate. Lower lip: Inner lobes obsolescent, outer lobes with nearly vertical mandibular lobes. Maxilla 1: Inner plate rounded, with 1 terminal spine; outer with oblique distal edge and simple terminal spine teeth; palp biarticulate, distal article 2 times as long as basal with 3 chisel-shaped and 1 normal spines. Maxilla 2: Inner plate with 2 terminal and 1 mediomarginal spines, heavily setose; outer plate longer than inner, distally narrow with 3 terminal spines. Maxilliped: Inner plate with 2 distal facial spines and 2 terminal "pits"; outer plate with serrate inner margin and 1 terminal chisel spine; palp with 4 articles, inner margin of article 2 produced medially, spinose; palp and plates normal for genus. Gnathopod 1: Coxa suboval; article 2 elongate with 3 anteromarginal spines; article 4 with 2 posterodistal spines; article 5 with spinose posterior lobe reaching along half of hind margin on article 6; palm transverse, corner defined by 2 stout spines; inner margin of dactyl serrulate proximally. Gnathopod 2: Coxa subquadrate; posterior margin of article 4 with 2-3 stout spines, distal edge with 1 long spine; article 5 with elongate posterior lobe reaching 90% as long as hind margin on article 6; article 6 distally expanded, anterior edge of outer face with 1-2 submarginal spines, otherwise unarmed; palm transverse with a row of minute spines, corner defined by 2 stout spines; dactyl attenuate, inner margin serrate on upper half. Pereopod 3: Coxa quadrate, longer than wide; anterodistal corner produced, margin with 4 spines; length ratios of articles 4,5,6–31:35:56, poorly spinose; dactyl attenuate. Pereopod 4: Coxa much larger than preceding coxa, posterior margin excavate; otherwise like pereopod 3. Pereopod 5: Coxa wider than long, bifid, article 2 expanded, with 4 anteromarginal spines; article 3 with 2 anteromarginal spines; article 4 with sharp posterior lobe and 3 spines on either margin; article 5 with 2 single and 1 pair of anteromarginal spines; article 6 with anteromarginal spine formula of 1,2,2,1; length ratios of articles 4,5,6–40:40:57, dactyl attenuate. Pereopod 6: Coxa wider than long, with expanded posterior lobe; article 2 expanded with 5 anteromarginal spines; article 3 with 1 anteromarginal spine; article 4 with sharp posterior lobe, either margin with 3 spines; article 5 with a single and 1 pair of anteromarginal spines and distal cluster of spines on either margin; article 6 with anteromarginal spine formula

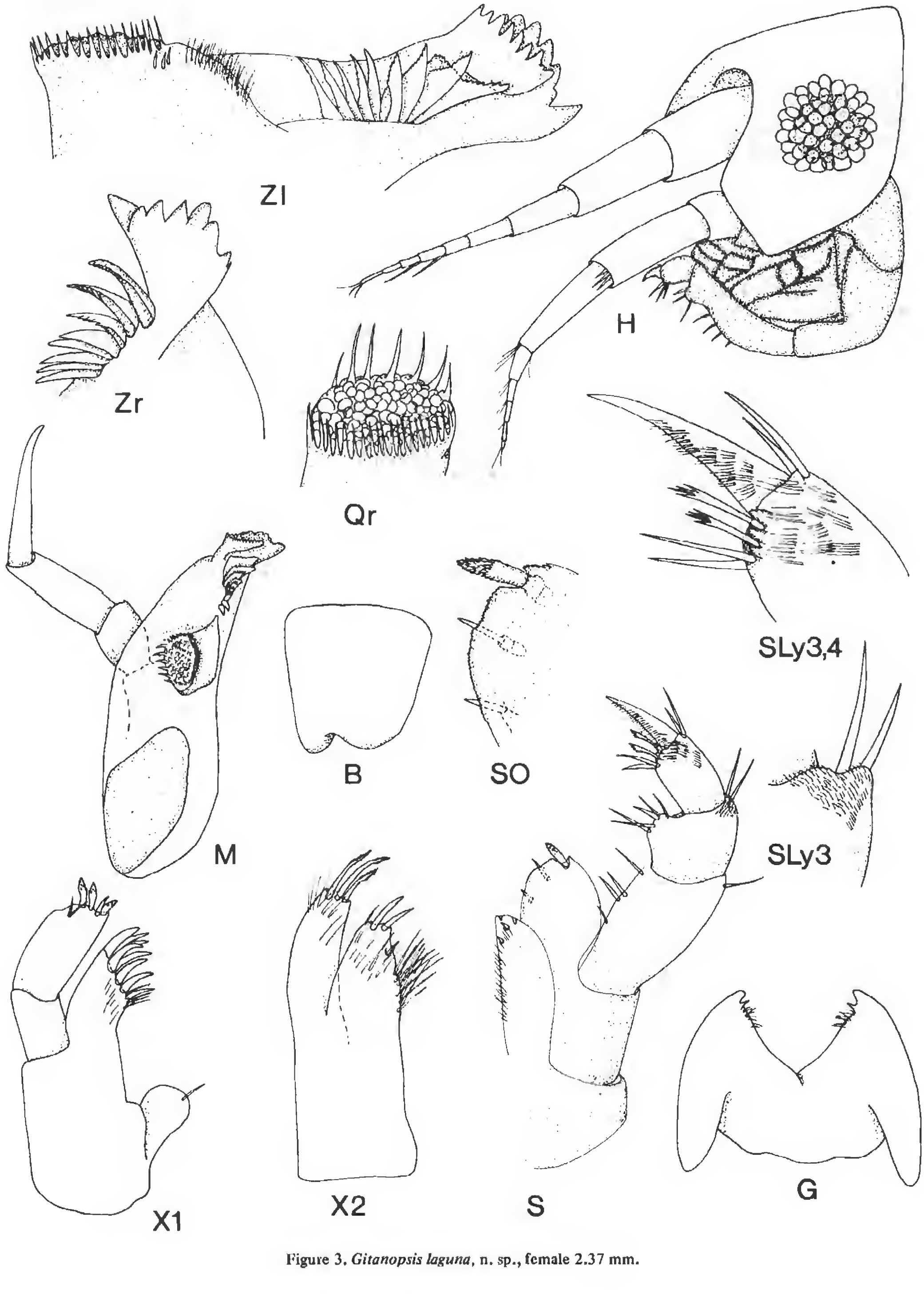

Figure 3. *Gitanopsis laguna*, n. sp., female 2.37 mm.

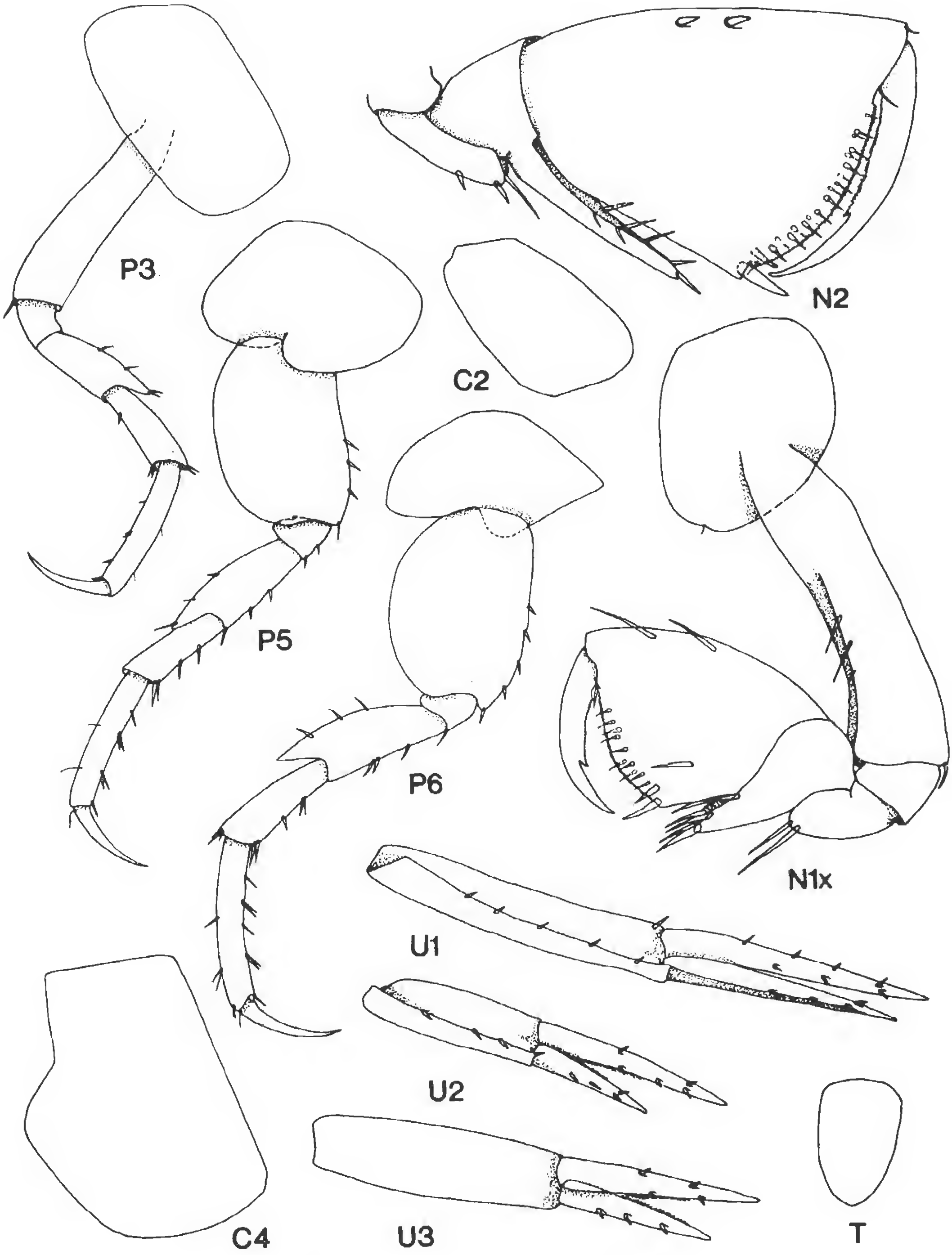

Figure 4. *Gitanopsis laguna*, n. sp., female 2.37 mm.

of 1,2,1,2,1; length ratios of articles 4,5,6–49:46:66, dactyl attenuate. Pereopod 7: Coxa like preceding one but reduced; pereopod longer than preceding one, otherwise similar. Epimera: Corners of plates unproduced, ventral margins of plates 2 and 3 with 2 spines each. Uropod 1: Peduncle longer than either 2 or 3, outer margin with 5 spines, inner with 1 distal spine; rami lanceolate, outer slightly shorter, with 3 outer and 1 inner marginal spines on distal part of ramus; inner ramus with 4 inner and 3 outer marginal spines; opposing margins of rami setulose. Uropod 2: Peduncle shorter than peduncles of uropods 1 or 3, armed with 4 outer marginal spines; outer ramus 0.6 times as long as the inner, with 3 outer and 1 inner marginal spines; inner ramus with 3 inner marginal and 2 outer marginal spines; opposing margins of rami setulose. Uropod 3: Peduncle elongate, unarmed; outer ramus slightly shorter than inner, outer margin with 3 spines; inner ramus with 2 spines on medial parts of either margin; opposing margins or rami setulose. Telson: longer than wide, tapering, apex rounded.

Male. unknown.

Types. Holotype, USNM 170758, female 2.37 mm; paratypes, 10 individuals, USNM 170759.

Type–locality. Holotype from West Bay, Galveston, Texas, 0.5 m depth. Paratype series from Laguna Madre, Texas, 1-2 m depth.

Material examined. The types and specimens from the following locations: Corpus Christi Bay, Texas; San Antonio Bay, Texas; Southern Laguna Madre near La Pesca, Mexico; and Laguna de Tamiaha near Cucharos, Mexico.

Distribution. Gulf of Mexico, bays and lagoons; shallow depths.

Relationships. *Gitanopsis laguna* is most closely related to two species: *G. vilordes* J. L. Barnard, 1962, from the California coast, and *G. tortugae* Shoemaker, 1933, from Tortugas, Florida. *Gitanopsis laguna* differs from *G. tortugae* in having a more rounded first coxa and a less rounded second coxa. *G. tortugae* also lacks the submarginal facial spines found on article 6 of gnathopod 2. *Gitanopsis laguna* differs from *G. vilordes* in having a more spinose lobe on article 5 of gnathopod 2 and in lacking the stout postero-distal spine on article 2 of that gnathopod. The eyes are more rounded in *Gitanopsis laguna* and the telson is shorter than in *G. vilordes*.

Ecological information. This species was found in shallow depths, 0.5 m, generally associated with algae. It appears to be restricted to higher salinity bays and lagoons as it was not found in offshore samples.

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Food of the Atlantic Croaker, *Micropogonias undulatus*, from Mississippi Sound and the Gulf of Mexico

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FOOD OF THE ATLANTIC CROAKER, *MICROPOGONIAS UNDULATUS*, FROM MISSISSIPPI SOUND AND THE GULF OF MEXICO[1]

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ABSTRACT The diet of the Atlantic croaker from Mississippi Sound has been examined for the first time. Over 83 taxa were encountered, or more than were reported from croaker in any other region. We also found 60 taxa, 36 of which overlapped with the above, in croaker from various offshore stations in the Gulf of Mexico. In Mississippi Sound the frequency of occurrence of items revealed primarily crustaceans followed by polychaetes, molluscs, fishes, and less common items, and, in the open Gulf, molluscs appeared slightly more often than in inshore croaker and than polychaetes in offshore fish. The diets were assessed according to length of fish, season, depth of water, and locality.

INTRODUCTION

In this study we examined the stomach and intestinal contents of many variously collected specimens of the Atlantic croaker, *Micropogonias undulatus*, a sciaenid, from Mississippi Sound and from adjacent water of the Gulf of Mexico. It presents specific identifications for numerous items and compares them, usually by taxonomic groupings, according to length of fish, season, depth of water, and geographic location.

The Atlantic croaker has an inferior mouth, sensory barbels, and coarse-straining gill rakers, all adaptations useful for feeding in and on the substratum. Chao and Musick (1977) have compared some of these features in several sciaenids and related them to feeding. The croaker usually comprises the most prevalent component of the industrial groundfish fishery in the Gulf of Mexico (Gutherz 1977) and is becoming increasingly important as a commercial foodfish (Gutherz et al. 1975). Moreover, it has always been an important component of the catch of sports fishermen in Mississippi who fish from banks and bridges and has long been recognized as a very abundant fish in the northern Gulf (e.g., Gunter 1938).

Mississippi Sound acts as a rich nursery region for juvenile croaker. Its salinities fluctuate from 0 to 37 parts per thousand (ppt), usually between 6 and 15 ppt (Christmas and Eleuterius 1973), and food for croaker and other inhabitants is typically plentiful. Soon after adult croaker spawn offshore, young fish up to 2 cm standard length (SL) begin occupying estuarine regions nearshore. This period extends from about October to February. About May, June, or July, a large proportion of that stock, then up to about 9 or 10 cm long, leaves for offshore Gulf water. Nevertheless, enough 2- and 3-year-old croaker remain in the Sound to support a sports fishery.

MATERIALS AND METHODS

Croaker were collected by a variety of means for different purposes. From Mississippi Sound, a total of 221 commercial-size fish between June 1976 and October 1977 were seasonally trawled, gill-netted, or hooked and immediately placed on ice for the primary purpose of removing and assessing the food contents. We trawled many other croaker from Mississippi Sound during 1970–1972 and 1975–1977 and maintained them alive for up to 2 days so that they could be critically examined for parasites. As for food contents, however, only the first few fish from each collection had nondigested items. Still, that material provided most of the data on croaker less than 7 cm SL (all measurements in this paper are standard lengths) plus a few from larger fish. Fishes from the Gulf of Mexico were collected from the R/V OREGON II and GEORGE M. BOWERS by members of the National Marine Fisheries Service (NMFS) between June 1974 and October 1977. Over 1,000 offshore fish came from many stations ranging from off Mobile Bay, Alabama, to off Galveston, Texas, from near shore in 11 meters depth to farther offshore at 90 meters. These fish were immediately frozen upon capture so that food contents and specific parasites could be preserved. Most had no food items when examined. Possibly as many as a half had their stomachs partially or entirely protruded by the rapid pressure difference when raised from relatively deep to surface water; consequently, they regurgitated their food.

Once removed from the measured fish, food contents were placed in 10% formalin for later identification. Because the nature of the study was not to deal with energy conversion and because the different fish had all possessed their food for different periods of time, no attempt was made to assess the volume or weight of food material.

RESULTS

Prevalence of recently fed Atlantic croaker with various dietary items appears as general, moderately general, and specific categories (Tables 1, 2, and 3). A large percentage (44%) of sampled croaker from Mississippi Sound had

[1]This study was conducted in cooperation with the U. S. Department of Commerce, NOAA, National Marine Fisheries Service, under PL 88–309, Project Nos. 2–262–R and 2–325–R.

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TABLE 1.

Percentage of Atlantic croaker of moderate and large sizes from inshore (I) and offshore (O) habitats containing various food items according to general category.

Fish Length in mm SL	95–198	76–195	200–350	200–351	Total	
	I	O	I	O	I	O
No. Exam.	131	1169	119	137	250	1306
No. w/Food	117	144	108	42	225	186
Food Item	Occurrence (%)					
Annelida	44.4	38.2	43.5	11.9	44.0	32.3
Mollusca	22.2	33.3	44.4	52.4	32.9	37.6
Crustacea	82.9	48.6	68.5	71.4	76.0	53.8
Fishes	17.9	0.7	28.7	14.3	23.1	3.8
Other animals	4.3	1.4	13.9	7.1	8.9	2.7
Plants	15.4		6.5	7.1	11.1	1.6
Detritus	22.2	1.4	15.7	9.5	19.1	3.2

TABLE 2.

Prevalence of feeding Atlantic croaker from Mississippi Sound with various stomach contents in relationship to season according to moderately general category.

Season	Spring	Summer	Fall	Winter	Total
No. Examined	62	100	56	32	250
No. with Food	52	87	54	32	225
Food Item	Occurrence (%)				
Hydrozoa		1.1			0.4
Annelida	48.1	50.6	37.0	31.3	44.0
Gastropoda	7.7			9.4	3.1
Scaphopoda			1.9		0.4
Pelecypoda	28.9	31.0	20.4	56.3	31.5
Cephalopoda			1.9		0.4
Ectoprocta		2.3			0.9
Echinoderma	3.9			3.1	1.3
Ostracoda	1.9	4.6			2.2
Cirripeda	1.9				0.4
Copepoda	3.9			12.5	2.7
Stomatopoda	15.4		3.7	3.1	4.9
Mysidacea	9.6	20.7	5.6	12.5	13.3
Amphipoda	28.9	50.6	9.3	3.1	28.9
Isopoda	3.9	11.5			5.3
Penaeidae	21.2	41.4	16.7	40.6	20.7
Palaemonidae	1.9	9.2			4.0
Callinectes	7.7	14.9	3.7	3.1	8.9
Other Decapoda	51.9	28.7		8.8	25.8
Other Crustacea	13.5		3.7	31.3	8.4
Insecta	3.9	9.2	1.9		4.9
Other Invertebrata	3.9	1.1		6.3	2.2
Osteichthyes	26.9	16.1	29.6	25.0	23.1
Algae	15.4	14.9	1.9		9.8
Vascular plants				3.1	0.4
Detritus	11.5	28.7	22.2	6.3	20.0

recently eaten annelids (Table 1). Of these, 79% shorter than 200 mm ate *Nereis succinea;* fewer large ones did (13%). Considering all the annelids together, possibly all polychaetes, little difference occurred between the percentage of relatively large and small fish feeding on them. Other primary dietary items consisted of pelecypods, amphipods, fishes, and penaeid shrimps (Table 2). *Mulinia lateralis* was the most prevalent pelecypod (in 28% of the 32% of croaker with bivalves), and both *Corophium louisianum* and *Ampelisca abdita* were commonly encountered amphipods (45 and 29% of the 29% of croaker with amphipods, respectively). Actually, the broad crustacean assemblage constituted the primary dietary group, being in 76% of the fed croaker. Mysids and blue crabs were common, in 13 and 9% of the fish, but less so than amphipods and shrimps. Most fish in the croaker stomachs had been digested beyond a stage necessary for identification.

Croaker-length, as already indicated, had some bearing on items consumed. Small croaker (95 to 198 mm) had more crustaceans than larger ones (83 versus 69%, respectively); whereas, an opposing relationship between item and croaker-length for both molluscs and fishes occurred: in 22 opposed to 44% and in 18 opposed to 29% of the croaker, respectively. When considering the crustaceans, we note the difference in abundance appears to reflect mostly amphipods and mysids which were found in 44 and 12% and in 19 and 7% of the large and small fish, respectively; the amphipod *Corophium louisianum* occurred in 21 and 4%, involving a total of 45% of the croaker with amphipods, and the mysid *Mysidopsis almyra* was in 16 and 4% of large and small fish, involving 77% of those fish with mysids.

Seasonality has an obvious influence on diet. Table 2 shows that the presence of amphipods, algae, portunid crabs, isopods, and miscellaneous crustaceans are most prominent during spring and summer and much less conspicuous during fall and winter. For example, amphipods occurred in 29 and 51% of the croaker in spring and summer, respectively, opposed to 9 and 3% in fall and winter. Other food items occurred more frequently during other seasons, such as penaeid shrimps in summer and winter.

Separate collections of smaller fish from the same locality provided comparative data on fish less than 70 mm long. Fish less than 25 mm fed on amphipods, ostracods, and copepods including unidentified harpacticoids, *Acartia tonsa, Pseudodiaptomus coronatus, Temora turbinata,* and others. Of 36 recently fed croaker 25 to 74 mm long, 25 contained copepods exclusively. Others contained *Palaemonetes pugio,* mysids, other shrimps, amphipods, fish remains, the spionid polychaete *Paraprionospio pinnata,* or a combination of items usually including copepods.

Atlantic croaker caught offshore demonstrated a different diet in many respects than croaker from Mississippi Sound. In two cases these results are listed in the same tables as data for inshore samples (Tables 1 and 3). The

TABLE 3.

Prevalence of feeding Atlantic croaker from Mississippi Sound and from combined offshore Gulf of Mexico stations containing various food items.

	Mississippi Sound (Fish Length in mm SL)			Gulf of Mexico (Depth in Meters)		
	95–198	200–350	Total	<30	≥ 30	Total
Number Fish Examined	131	119	250	77	111	188
Number Fish with Food	117	108	225	77	109	186
Food Item			Occurrence (%)			
Hydrozoan	0.9		0.4	1.3		0.5
Platyhelminth						
Stylocus ellipticus	0.9		0.4			
Nemertean		1.9	0.9			
Polychaetes						
Capitallid or oligochaete	2.6		1.3			
Diopatra cuprea	0.9	1.9	1.3	2.6		1.1
Drilonereis sp.				1.3		0.5
Glycera americana	0.9	4.6	2.7			
Glycinde sp.	4.3		2.2	1.3		0.5
Goniada sp.		0.9	0.4			
Hypaniola florida	1.7	0.9	1.3			
Nereis sp.		1.9	0.9	2.6		1.1
Nereis succinea	35.0	5.6	20.9			
Paraprionspio pinnata	0.9		0.4			
Pectinaria gouldii	0.9		0.4			
Unidentified polychaetes	7.7	33.3	20.4	49.4	18.3	31.2
Unidentified terebellid				2.6		1.1
Gastropods						
Acteocina canaliculata		0.9	0.4			
Anachis sp.		0.9	0.4	2.6		1.1
Nassarius acutus					0.9	0.5
Natica canrena					1.8	1.1
Neritina reclivata					0.9	0.5
Retusa sp.		0.9	0.4			
Sinum perspectivum				2.6		1.1
Unidentified gastropod		4.6	2.2	2.6		1.1
Scaphopod						
Dentalium sp.					3.7	2.2
Pelecypods						
Amygdalum papyrium	7.7		4.0			
Anadara transversa				1.3		0.5
Corbiculid remains				1.3		0.5
Corbula sp.		0.9	0.4		0.9	0.5
Ensis minor	0.9	0.9	0.9			
Ischadium recurvum	4.3		2.2			
Macoma mitchelli	0.9	0.9	0.9			
Mulinia lateralis	9.4	8.3	8.9	12.9		5.4
Mytilopsis leucophaeuta	0.9		0.4			
Nuculana concentrica	0.9	20.3	10.2	10.4	22.9	17.8
Tagelus plebeius	1.9	0.9	1.3			
Tellina sp.	1.7	1.9	1.8			
Varicorbula operculata					0.9	0.5
Unidentified bivalve remains	0.9	10.2	5.3	1.3	1.8	1.6
Cephalopod						
Octopus sp.		0.9	0.4			
Ostracod	0.9		0.4		1.8	1.1
Cirripeds						
Balanus improvisus	3.4		1.8			
Unidentified barnacle	0.9		0.4			

TABLE 3 (Continued).

Prevalence of feeding Atlantic croaker from Mississippi Sound and from combined offshore Gulf of Mexico stations containing various food items.

	Mississippi Sound (Fish Length in mm SL)			Gulf of Mexico (Depth in Meters)		
	95–198	200–350	Total	<30	≥30	Total
Number Fish Examined	131	119	250	77	111	188
Number Fish with Food	117	108	225	77	109	186
Food Item	Occurrence (%)					
Copepods						
Calanoid	0.9	3.7	2.2			
Unidentified copepod	0.9		0.4		1.8	1.1
Stomatopods						
Squilla diceptrix					1.3	0.5
Squilla edentata		0.9	0.4			
Squilla empusa	0.9	3.7	2.2	5.2		2.2
Squilla remains	0.9	4.6	2.7	1.3	11.9	7.5
Mysid						
Mysidopsis almyra	20.5	6.5	13.8			
Cumacean		6.5	3.1		0.9	0.5
Amphipods						
Ampelisca abdita	14.5	1.9	8.4			
Ampelisca sp.	3.4	3.7	3.6		0.9	0.5
Cerapus sp.	11.9	4.6	8.4			
Corophium louisianum	21.4	3.7	12.8			
Gammarus mucronatus	5.1		2.7			
Gammarus tigrinus	1.7		0.9			
Haustorid		0.9	0.4			
Melita nitida	2.6		1.3			
Unidentified amphipod	0.9	2.8	1.8			
Tanaidacean						
Leptochela sp.		9.3	4.4		0.9	0.5
Isopods						
Cassidinidea lunifrons	0.9		0.4			
Cyathura polita	2.6	5.6	4.0			
Edotea montosa	0.9		0.4			
Isopod remains	0.9		0.4			
Penaeids						
Parapenaeus longirostris		0.9	0.4		1.8	1.1
Penaeus aztecus	3.4	5.6	4.4			
Penaeus remains	30.8	21.3	26.2	3.9	8.3	6.5
Penaeus setiferus	1.7	0.9	1.3			
Sicyonia dorsalis					1.8	1.1
Trachypenaeus sp.				1.3		0.5
Sergestid						
Acetes americanus				2.6	4.6	3.8
Carideans						
Alpheus floridanus		9.3	4.4		8.3	4.8
Alpheus sp.				1.3	0.9	1.1
Ogyrides limicola	1.7		0.9	1.3	0.9	1.1
Palaemonetes pugio	5.9	1.9	4.0			
Synalpheus townsendi		0.9	0.4	1.3		0.5
Unidentified caridean		2.8	1.3	1.3	3.7	2.7
Anomurans						
Albunea gibbesi		0.9	0.4	3.9	0.9	2.2
Callianassa jamaceae	1.7	2.8	2.2			
Callianassa remains		0.9	0.4		0.9	1.1
Pagurus spp.	0.9		0.4	2.6	21.1	13.4

TABLE 3 (Continued).

Prevalence of feeding Atlantic croaker from Mississippi Sound and from combined offshore Gulf of Mexico stations containing various food items.

	Mississippi Sound (Fish Length in mm SL)			Gulf of Mexico (Depth in Meters)		
	95–198	200–350	Total	<30	≥30	Total
Number Fish Examined	131	119	250	77	111	188
Number Fish with Food	117	108	225	77	109	186
Food Item	Occurrence (%)					
Brachyurans						
Calappa sp.					0.9	0.5
Callinectes remains		2.8	1.3			
Callinectes sapidus	11.1	4.6	8.0	2.6		1.1
Callinectes similis		1.9	0.9			
Chasmocarcinus mississippiensis					0.9	0.5
Eurypanopeus depressus	1.7		0.9			
Euryplax nitida		6.5	3.2			
Hepatus epheliticus				1.3		0.5
Hexapanopeus angustifrons		0.9	0.4		0.9	0.5
Leiolambrus nitidus		1.9	0.9	1.3	0.9	1.1
Pinnixa sp.					0.9	0.5
Portunus gibbesi				1.3		0.5
Portunus spp.		3.7	1.8		4.6	2.7
Raninoides louisianensis					2.8	1.6
Rhithropanopeus harrisi	17.1	2.8	10.2			
Solenolambrus sp.					0.9	0.5
Unidentified branchyuran larva		0.9	0.4			
Unidentified goneplacids		0.9	0.4	6.5	13.8	10.7
Unidentified xanthid	5.1	4.6	4.9	1.3		0.5
Unidentifiable decapod remains		2.8	1.3			
Insect						
Chironomid midge larva	6.8	2.8	4.9			
Ectoprocts						
Bowerbankia gracilis	0.9		0.4			
Membranipora arborescens	0.9	0.9	0.9			
Chaetognath				1.3		0.5
Echinoderms						
Echinoid remains		2.8	1.3		0.9	0.5
Hemipholis elongata				3.9	0.9	2.2
Fishes						
Anchoa hepsetus		0.9	0.4			
Anchoa mitchilli	1.7	5.6	3.6	2.6		1.1
Anguilliform remains	0.9		0.4			
Gobiosoma bosci	2.6	0.9	1.8			
Microdesmus longipinnis		0.9	0.4			
Symphurus plagiusa		0.9	0.4			
Unidentifiable fish parts	11.1	24.0	17.3	7.8	1.8	4.3
Unidentifiable goby	0.9	0.9	0.9			
Plants						
Algae and unidentified plant matter	18.8	1.9	10.7	1.3		0.5
Sea grass		0.9	0.4			
Detritus and other organic matter	23.1	17.6	20.4	7.8		3.2

offshore croaker feed most commonly on crustaceans (54% of the fish with food), but also on molluscans and annelids (38 and 32%, respectively). Crustaceans occurred most frequently in samples from water deeper than 30 meters (69 versus 33% in water less than 30 m) and from larger fish (71 versus 49% in relatively short fish). Actually, crustaceans, the general food most frequently observed to be consumed from both inshore and offshore habitats, had a higher prevalence in inshore croaker. In fact, of the major general categories, only molluscs occurred in more offshore croaker,

and then not substantially (Table 1). Offshore molluscs, primarily bivalves, show similar relationships as the offshore crustaceans with water-depth and with fish-length. On the other hand, offshore annelids, primarily polychaetes, occurred most commonly in the shallower samples (in 52 versus 18% of the fish) and in smaller fish (38 versus 12%). Other less common items such as fishes, plants, and detritus all occurred slightly more frequently in the large croaker from shallower offshore water.

Specific animals, as expected, typically occurred most frequently in specific regions. For examples, the bivalve *Nuculana concentrica* occurred most frequently in deeper water as did the hermit crabs, *Pagurus* spp. We also point out that more smaller fish had hermit crabs than those fish longer than 20 cm. On the other hand, the stomatopod *Squilla empusa* occurred in fish only from the shallower localities.

DISCUSSION

The long list of different food items in the Atlantic croaker constitutes the most important aspect of this study. Differences in dietary organisms taken from inshore and offshore samples reflect a difference in components of the communities from the two general regions. A more complete delineation of the localities would have emphasized the differences in communities even more.

Stomach contents of croaker had not been previously reported from Mississippi waters. Our data reveal some differences among samples according to depth, length of fish, and season, as well as to locality. In addition to mere examination of tables listing and comparing the percentage/frequency of occurrence for different items, we compared some of the values statistically. For example, using Wilcoxon's signed rank test (Steel and Torrie 1960:402) we accept the hypothesis that the frequencies of the various food items differ between fish less and greater than 200 mm in both Mississippi Sound (T_{lesser} = 147.5 and 147.5 > $61_{\alpha=.01}$, n=24) and the Gulf of Mexico (T_{lesser} = 33 and 33 > $23_{\alpha=.01}$, n=17); however, the ranks of the frequencies of those items do not significantly differ between inshore and offshore stocks (T_{lesser} = 61.5 and 61.5 < $68_{\alpha=.01}$, n=25). Still a Spearman's rank test (Fritz 1974) suggests that compared ranks in all three comparisons are correlated: r_s = 0.582, 0.627, and 0.521 with "t" = 3.360 > $2.819_{\alpha=.01}$, 22df, 3.116 > $2.947_{\alpha=.01}$, 15df, and 2.924 > $2.807_{\alpha=.01}$, 23df, respectively. A Friedman test (Conover 1971) was used to compare the generalized items by season. In this case, T = 5.06, and 5.06 < $11.34_{\alpha=.01, 3df}$, allowing us to accept the null hypothesis that no difference exists for the croaker's diet among any of the seaons. This result, however, might be misleading because of the high prevalence of fish in the croaker stomachs during the fall and the low prevalence during the summer. Inspection of the less generalized items in Table 2 shows a lower prevalence in fall than in other seasons for crustaceans, as well as other variations.

Parker (1971) used the Spearman's rank test to compare differences in ranked frequencies between food items from Texas and Louisiana in different croaker-length groups. In order to compare our findings for large fish with his, we joined some less common groups together, deleted the group for mud and sand since we did not always document that category in our material, ranked the values, and compared them with the corresponding ones for croaker from Louisiana and Texas. The results of the tests do not indicate that a correlation exists between the paired groups (r_s = 0.467 and 0.155 when compared with values from Louisiana and Texas, respectively; "t" = 2.243 and 0.667 with those values less than $t_{\alpha=.01,\ 18df}$ = 2.878). When ranking the least frequent item as 1 (as suggested by Fritz [1974]) rather than the most frequent one, we obtained r_s = 0.465 and 0.138 with "t" = 2.231 and 0.589, indicating the same conclusions. Additionally we used Wilcoxon's test and accept the alternative hypothesis that the croaker's diet in Mississippi Sound differs from that encountered in both Louisiana (T_{lesser} = 45.5, 45.5 > $38_{\alpha=.01}$, n=20) and Texas (T_{lesser} = 56, 56 > 38).

Several analyses of the croaker's food contents have been conducted. Of these, no reason exists not to believe that the croaker acts opportunistically, feeding on any easily available prey. Some learning behavior may occur because specific individuals from a collection of confined fish occasionally had exclusively fed on specific food items different from those found in their counterparts. This observation was especially conspicuous for small croaker heavily packed with *Pseudodiaptomus coronatus, Corophium louisianum,* or other small crustaceans, but it also occurred for larger croaker feeding on large prey. Darnell (1958) noted the same tendency for a few young croaker to specialize on chironomids, mysids, or amphipods. We found that most individuals fed on a variety of items.

A large number of authors have reported mostly unidentified food items from croaker. One paper by Stickney et al. (1975), however, presented an extensive list with 58 different taxa in croaker from Georgia. We found over 83 taxa in Mississippi Sound and 60 in the Gulf including 36 that overlapped between the two regions. Chao and Musick (1977) referenced most of the studies from the Atlantic coast. Those studies from the Gulf of Mexico are by Gunter (1945), Reid (1955), Reid et al. (1956), Darnell (1958), Inglis (1959), Avault et al. (1969), Hanson (1969), Fontenot and Rogillio (1970), Parker (1971), Day et al. (1973), Diener et al. (1974), Weaver and Holloway (1974), Roussel and Kilgen (1975), and Chen (1976).

Croaker from different localities feed on the same general items, but often in different proportions and on different specific components. In general, croaker feed on crustaceans, polychaetes, pelecypods, fishes, detritus, and miscellaneous invertebrates and plants. Several factors obviously dictate the proportions and compositions of these food items, but

these factors have been inadequately studied. Reid (1955) found 45% of a sample from East Bay, Texas, fed on molluscs and 13% on shrimp. After construction of Rollover Pass, an entrance allowing introduction of water from the Gulf into the Bay, Reid et al. (1956) found a decreased frequency of croaker, and of the sample, 98% fed on molluscs, but still 13% on shrimp. Data from our tables reveal some differences according to length of fish, season, locality, and depth of water. Other papers also revealed differences related to various variables. As an example, Farrell (1970) showed a seasonal variation in amphipod consumption with most amphipods eaten in spring and early summer in Mississippi Sound, but differing somewhat by exact locality. Species of *Corophium* predominated.

Commercial shrimps and blue crabs constituted a sizeable portion of the diet in croaker from Mississippi and a few, but not all, other Gulf locations. In spite of the high prevalence of penaeids in localities inhabited by the croaker in Georgia and North Carolina, few individual croaker ate these shrimp; rather, they utilized *Neomysis americana* (Stickney et al. 1975).

Stickney and coworkers pointed out that few taxa occurred in large numbers of croaker, citing *N. americana* in 17% of the croaker as the most frequent item the authors encountered. We observed several food items that occurred more often. In croaker from Mississippi Sound, *Penaeus* spp. (in most cases, the remains of *Penaeus aztecus* were not differentiated from those of *P. setiferus*) occurred in 30% of the fish and the polychaete *Nereis succinea* in 21%. Members of neither taxon was common offshore (5% of offshore croaker did contain *Penaeus* spp.), but hermit crabs in the genus *Pagurus* occurred in 13% of the offshore fish, 21% of those fish from deeper than 30 m, and rarely in croaker from the Sound. The bivalve *Nuculana concentrica* was found in 18% of the offshore croaker and 10% of the inshore ones.

Primary species comprising each general group differ from habitat to habitat. As an example, we consider clams. Whereas the razor clam constitutes the most common bivalve food item for the croaker along many Atlantic coast localities, its role is substituted elsewhere. *Rangia cuneata* fills this role in Lake Pontchartrain, *Mulinia lateralis* and *Nuculana concentrica* in Mississippi Sound, and *Macoma mitchelli* in East Bay, Texas. In regions where more diversified bivalve populations occur such as in the Gulf of Mexico, dominant forms may be less conspicuous. *Nuculana concentrica* occurred in many of the croaker we examined, but large samples from other sites would probably yield other common species.

Our offshore samples do not represent a single locality. In fact, fish with food came from 32 different stations over a 3-year period. As indicated earlier, most individuals did not have food present and obtaining food data was a secondary mission. Nevertheless, our data reveal some valuable generalizations about the food of the offshore Gulf croaker.

Food contents of croaker also collected by the NMFS during a portion of the same period, but with only two overlapping stations, were analyzed by Chen (1976). She grouped data from different stations and found contents in 300 croaker 26 to 339 mm SL to have a frequency of occurrence greatest for polychaetes (53%), followed by natantian decapods (47%), mysidaceans (20%), amphipods (12%), brachyurans (11%), brittle stars (11%), and other less common items. Ninety percent of the croaker had organic or inorganic matter, presumably most of which were partially digested items.

The primary differences between our findings and those of Chen are that in our samples molluscs occurred more frequently and the diet was much more diversified. We did not encounter as many polychaetes and found no mysids or ophiuroids. According to Chen's graphs separating diet by size of fish, the fish in three unspecified size-groups generally appeared to have similar diets.

Comparison of Chen's and our data, just like comparison of most data from the same or from different areas, shows that portions of croaker diet may vary significantly among compared samples. The difference probably primarily reflects the availability of the specific items at a specific collecting site.

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Addenda and Errata to Overstreet, R. M. and R. W. Heard. 1978. Gulf Research Reports 6(2):145-152.

All the following items refer to Table 3.

1. Under pelecypods, corbiculid remains should read corbulid remains.

2. Under amphipods, *Gammarus tigrinus* and *Melita nitida* may be undescribed species most similar to those two listed species. Unidentified amphipods include *Ampelisca agassizi*, *Unicola* sp., and others.

3. Under *Leptochela* sp. in the tanaidacean section, the inshore material actually was *Leptochelia* sp. (=*Hargaria rapax*?) and *Kalliapseudes* sp. *Leptochela* sp., listed from relatively deep offshore water, is a caridean shrimp.

4. A group of 16 fish collected 24 March 1977 may confuse the results. Ten had food items which were *Alpheus floridanus* in six, *Squilla* spp. in four, *Euryplax nitida* in two, *Leiolambrus nitidus* in two, *Portunus* sp. in one, and urchin remains in two. The fish were apparently trawled from high-salinity water in a pass at the barrier islands and not representative of Mississippi Sound.

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A Bibliography of the Rhizocephala (Crustacea: Cirripedia)

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A BIBLIOGRAPHY OF THE RHIZOCEPHALA (CRUSTACEA: CIRRIPEDIA)

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ABSTRACT A bibliography of parasitic barnacles of the suborder Rhizocephala, including 490 titles, is presented. Scientific works from 1787 to present are listed.

INTRODUCTION

The Rhizocephala represent one of the suborders of the crustacean order Cirripedia. All are parasites of other crustaceans, principally decapods (crabs, shrimp, and their allies).

A rhizocephalan larva penetrates a susceptible host, and ramifies throughout the host in a root-like system called an interna. After growth internally in the host, the parasite grows an external sac-like structure, filled mainly with sexual organs, called an externa. The externa is attached to the abdomen of its host by a short stalk, from which roots pass into the interior of the host, deriving nourishment from the body fluids of the host.

Rhizocephalans can cause "parasitic castration" of their hosts, and the secondary sexual characteristics of the host may be altered. Parasitized male crabs may have a broadening of the abdomen so that it resembles the abdomen of a normal female; they also may have deformed pleopods. The gonads are affected in two main ways: by retardation of development, and by actual destruction.

After the externa drops off, the interna generally slowly degenerates. The host may recover and resume a normal life; however, it is likely that it will remain stunted and can never carry on normal reproductive processes. The host's gonads can recover from the effects of castration if it is freed from the parasite. Females regenerate functional ovaries and males that are slightly modified regenerate testes. Males that are altered so that they exhibit the external characters of females may regenerate a hermaphroditic gonad.

Rhizocephalans do not prevent molting of the host as long as they are internal. Parasitized brachyuran crabs do not molt, as a rule, after the rhizocephalan has become external.

As rhizocephalans parasitize a number of commercially important decapods throughout the world, this bibliography should be of use to parasitologists and persons involved in the study of decapods.

We have undoubtedly omitted some references, and would appreciate any additions that can be made to this listing.

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SHORT COMMUNICATIONS

SILICA AND ASH IN THE SALT MARSH RUSH, *JUNCUS ROEMERIANUS*

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ABSTRACT Silica content of living rhizomes from the perennial salt marsh rush *Juncus roemerianus* had values of 0.34, 0.20, and 0.60% of dry weight in three morphologically distinct populations along the Mississippi coast and was directly related to available silica content of the soil (29.7, 17.0, 169.6 mg/100g soil, respectively). On the other hand, living leaves had about the same average silica content (0.93, 0.87, 0.90% of dry weight). The silica content of living leaves varied from 0.142% in younger leaves to 1.520% in older ones. Similarly, rhizomes also increased in silica content with age, varying from 0.137% in younger portions to 1.030% for older ones. Mature leaves collected in October all had a higher average silica content (0.737%) than those collected in April (0.413%), indicating that silica content also increases over the growing season. Decomposed leaves (dead-standing) had a relatively high silica content of 1.81%, obviously reflecting a loss of organic matter and soluble minerals. Roots contain considerable silica, but reliable results were not possible as the soil could not be completely removed from them. Petrographic microscope studies showed that the silica was clear, colorless and isotropic with a refractive index of 1.43, all properties typical of the mineral opal. No α-quartz was present, as occurs in some species of *Juncus*. The silica was deposited in a sheet made up of small, irregular phytoliths arranged in rows lengthwise in the leaves. Ash percentages were much higher than those for silica and no definite conclusions could be drawn from their variation. In comparison to the maximum silica content of leaves from *Juncus interior* (3.21%), the concentrations found in leaves of *J. roemerianus* were relatively low.

INTRODUCTION

Silica occurs in numerous vascular plants, including the rushes *Juncus interior* Weig. and *Juncus bufonius* L. Lanning (1972) showed that these rushes contained much silica and that the content of *J. interior* increased nearly eight-fold over the growing season. Both *J. interior* and *J. bufonius* contain opaline silica and α-quartz as do other plants such as Lantana (Lanning et al. 1958). From an extensive review of the literature, Ishizuka (1971) states that the presence of silica increases the rigidity of the leaves of the rice plant, causing them to become erect. He also cites strong evidence that the presence of silica increases the resistance of plants to fungal diseases and insect attack.

Juncus roemerianus Scheele is a common rush of salt marshes throughout the coastal area of Mississippi, southeastern Louisiana and other parts of the Gulf and Atlantic coasts (Eleuterius 1975). The rush grows erect, with stiff terete leaves, that arise terminally from short stems near the surface of the marsh (Eleuterius 1975, 1976). The leaves are coarse, long lasting in some populations, resistant to fungal attack and infrequently grazed by insects. This knowledge of *J. roemerianus* led to the hypothesis that the presence of silica may account for the stiff, persistent and resistant leaves.

This study was designed to determine: (1) if present, the types and quantity of silica; (2) the ash (A) and silica (S) contents of the various parts of *Juncus roemerianus* plants; (3) the A and S contents of plants from three morphologically distinct populations; (4) the silica content of the marsh soil in relation to concentration in the rush plants; (5) seasonal differences, if any; and (6) the A and S contents of young leaves and rhizomes in comparison to older ones.

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METHODS AND MATERIALS

Juncus roemerianus plants were collected from several populations at different locations near Ocean Springs, Mississippi (Figure 1): Belle Fontaine Beach (BFB) marsh; Weeks Bayou (WB) marsh; Salt Flats (SF). Samples with long rhizomes (LR) and a single plant (SP) were taken from Simmons Bayou Spoil (SBS). Plants found at WB have mature leaves 3 to 5 feet in length, while those at SF and BFB have leaves 1 to 1.5 and 5 to 7.5 feet in length, respectively. Decomposed leaf material was collected from the peripheral and terminal portions of Simmons Bayou marsh. Specific dates of collections are given with the tables of results.

The plant materials were thoroughly washed and then air dried at 110°C. Whole plants were separated into aboveground parts, rhizomes and roots. All plant materials were ground in a Wiley mill before analysis. Silica content of plant material was determined by classical gravimetric techniques using platinum crucibles. The material was ashed at about 500°C and the ash treated repeatedly with 6N hydrochloric acid to remove other mineral impurities. The silica was filtered out and ignited. The silicon dioxide content

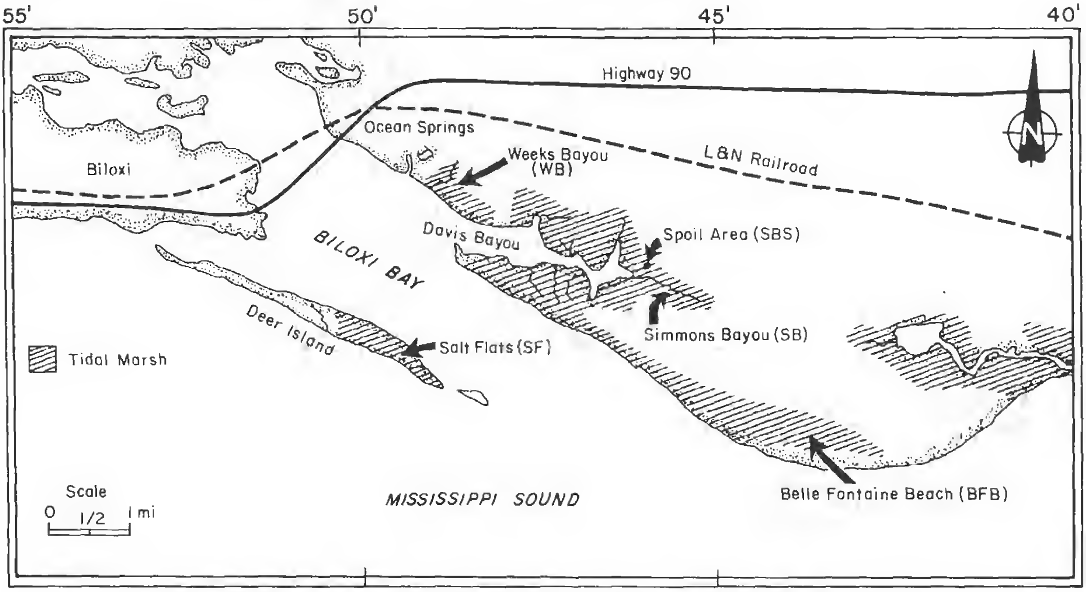

Figure 1. The study areas of the tidal salt marsh rush, *Juncus roemerianus*, were located at Belle Fontaine Beach; Weeks Bayou, and Salt Flats. The rush formed monotypic stands at each location.

was determined as the difference of weights before and after treatment with hydrofluoric acid.

Available silica in soil was determined as acetate soluble silica according to the Imaizumi and Yoshida (1958) modifications of Kahler's method (1941). A 10-gram sample of soil was extracted by 100 ml of 1N acetate buffer of pH 4.0 for 5 hours at 40°C. To a 10-ml aliquot of extract, 5 ml of 0.60N hydrochloric acid and 5 ml of ammonium molybdate (102 grams per liter) were added. After the mixture had stood for 3 minutes, 10 ml of sodium sulfite (170 grams per liter) were added. This mixture was allowed to stand 10 minutes, and then absorbance at 634 nm was measured with a Bausch and Lomb Spectronic 20. The pH of the soil was determined with a Coleman pH meter. Mixtures of equal volumes of soil and water were used for the pH determinations.

Spodograms were prepared by the Ponnaiya (1951) modification of the Uber (1940) method. The material to be examined was placed between microscope slides, and then ashed in a muffle furnace at 450° to 500°C. The ash was prepared for microscopic examination and photography by removing the upper slide, adding Canada balsam directly to the mass and covering with a cover glass. A petrographic microscope was used to study the nature of silica deposits. Several specimens from each location were examined.

RESULTS AND DISCUSSION

Petrographic microscope studies of silica from ash of *Juncus roemerianus* showed it to be clear, colorless and isotropic with an index of refraction of 1.45. These properties are characteristic of the mineral opal (Lanning et al. 1958). No α-quartz was present although it occurs in *Juncus interior* Weig. and *Juncus bufonius* L. The silica is deposited in sheets which are made up of rows of small irregular phytoliths arranged lengthwise in the leaves. Some fibers are also present (Figure 2).

The soils differed considerably between the three marshes. The soil for SF plants was sandy, had a pH of 9.10 and an acetate-available silica content of 29.7 mg/100g of soil. The BFB and WB soils were a clay type and had pH values of 5.77 and 7.00, respectively. The acetate-available silica contents of BFB and WB soils were quite high, 17.0 and 169.0 mg/100g soil, respectively.

The leaves of plants in the sandy alkaline soil (SF) grew from 1 to 1.5 feet tall. The leaves from other locations (see Methods section) were much taller (WB = 3 to 5 feet; BFB = 5 to 7.5 feet).

Results from samples collected in January (Table 1) show that silica concentration is much higher in the leaves than the rhizomes. The leaves of plants from all three locations had about the same silica percentage. The WB rhizomes growing in the soil with high available silica content had a much higher percentage of silica than rhizomes from the other locations. Ash concentrations were much higher than the silica concentrations and were lowest in SF plants.

Living leaf material from the three locations (Table 1) all showed a considerably higher silica percentage in samples collected in October than those collected in April. This

Figure 2. Spodogram of silica deposited in a *Juncus* leaf (100 X). Note the small, irregular phytoliths (P) and some fibers (hyaline streaks, F).

TABLE 1.

Ash and silica content of living *Juncus roemerianus* from Belle Fontaine Beach (BFB) marsh, Weeks Bayou (WB) marsh, and Salt Flats (SF) on Deer Island. Collections were made during January 1977. Composition of living leaves taken in April (A) and October (O) 1976 from the same three populations are also shown.

	Leaves		Rhizomes	
Sample No.	% Ash	% Silica	% Ash	% Silica
BFB–1	4.13	0.93	3.53	0.21
BFB–2	4.28	0.83	5.10	0.21
BFB–3	4.39	0.79	4.47	0.28
BFB–4	5.12	0.80	4.20	0.23
BFB–5	4.75	0.94	3.24	0.08
BFB–6	5.25	0.94	4.43	0.18
Average	4.65	0.87	4.16	0.20
WB–1	4.93	0.95	5.34	0.40
WB–2	5.40	1.24	5.31	0.93
WB–3	4.90	0.86	4.74	0.43
WB–4	5.35	0.89	5.02	0.36
WB–6	4.70	1.11	6.55	1.28
Average	5.10	0.90	5.50	0.60
SF–1	4.26	0.90	3.57	0.22
SF–2	4.36	1.22	5.12	0.37
SF–3	3.80	0.88	3.64	0.43
SF–4	4.15	1.03	4.03	0.37
SF–5	3.98	0.83	4.27	0.42
SF–6	3.85	0.71	4.02	0.23
Average	4.07	0.93	4.11	0.34
BFB–A	4.93	0.56		
BFB–O	4.47	0.69		
WB–A	4.69	0.34		
WB–O	4.40	0.83		
SF–A	3.95	0.34		
SF–O	3.68	0.69		

increase over the growing season corresponds with results obtained by Lanning (1972) for other *Juncus* plants and Lanning and Linko (1961) for *Sorghum* plants.

The results of studies on plants to compare the silica concentrations of younger and older plant materials are shown in Table 2. For this study the rhizomes were cut in two, and the older halves analyzed separately from the younger. In all cases older leaves and rhizomes had considerably higher silica percentages than younger ones. Decomposed leaf material had a much higher silica percentage than the living material analyzed. Loss of organic matter and soluable mineral matter obviously resulted in this higher silica percentage. Silica constitutes a small fraction of the mineral matter in the plants since the ash percentages were much higher. Root analyses were not accurate since it was not possible to remove all the soil. Ash content of the roots was abnormally high indicating that silica must also be too high to be accurate.

TABLE 2.

Ash and silica contents of young and old leaves, rhizomes and leaves of a single clump [clone or single plant (SP)] about 45 cm in diameter, of *Juncus roemerianus* collected from Simmons Bayou Spoil (SBS). Long rhizomes (LR), 30 to 45 cm in length, bearing intact shoots and roots were dug from a larger clump located at SBS and separated into younger and older parts. Comparative samples were also taken from three populations: Belle Fontaine Beach (BFB) marsh, Weeks Bayou (WB) marsh and Salt Flats (SF) at Dear Island. Composition of decomposed (dead-standing, BFB) leaf material is also shown. All samples were taken during June 1977.

Plant Part	% Ash	% Silica
Single plant (small clump) — SBS–SP		
Young leaves	4.85	0.142
Old leaves	4.99	0.599
Dead leaves	4.63	0.783
Rhizomes	6.15	0.317
Roots	10.40	1.25
Long rhizomes with intact shoots and roots — SBS–LR		
Younger half of rhizomes	3.97	0.270
Older half of rhizomes	3.30	0.441
Leaves on younger half of rhizomes	4.94	0.960
Leaves on older half of rhizomes	4.47	1.520
Roots	15.36	2.53
Long rhizomes with intact shoots and roots from three populations		
BFB:		
Rhizomes – younger half	7.35	0.137
Rhizomes – older half	9.92	0.506
Roots	13.30	0.632
WB:		
Rhizomes – younger half	8.95	0.418
Rhizomes – older half	9.10	0.447
Roots	15.90	1.18
SF:		
Rhizomes – younger half	7.78	0.705
Rhizomes – older half	9.63	1.03
Roots	14.09	1.82
Decomposed leaf material — BFB	3.93	1.81

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Occurrence of *Mysidopsis almyra* Bowman, *M. bahia* Molenock and *Bowmaniella brasiliensis* Bacescu (Crustacea, Mysidacea) from the Eastern Coast of Mexico

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OCCURRENCE OF *MYSIDOPSIS ALMYRA* BOWMAN, *M. BAHIA* MOLENOCK AND *BOWMANIELLA BRASILIENSIS* BACESCU (CRUSTACEA, MYSIDACEA) FROM THE EASTERN COAST OF MEXICO

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ABSTRACT Three species of mysids, *Mysidopsis almyra, M. bahia* and *Bowmaniella brasiliensis* are recorded for the first time from four locations along the eastern coast of Mexico. Data on geographical distribution, population structure, length, brood size, and morphological variation are given.

INTRODUCTION

Only two mysid species have been reported from the shallow waters along the eastern coast of Mexico between the Rio Grande and the Yucatan peninsula. Bacescu (1968) reported *Bowmaniella dissimilis* (Coifmann) from Veracruz, Veracruz, and Price (1975) reported *Metamysidopsis swifti* Bacescu from Tuxpan and Punta de Anton Lizardo in Veracruz. This paper reports the collection of three additional mysid species from four locations along the eastern coast of Mexico in May 1973.

MATERIAL AND METHODS

Collections were made with a 1.5 m hand-drawn beam trawl (Renfro 1963) and preserved in 5% formalin. Temperature was measured with a hand-held mercury bulb thermometer and salinity was measured with a refractometer.

RESULTS AND DISCUSSION

Collection sites are shown in Figure 1. The northernmost collection was made 1 km west of La Pesca, Tamaulipas (23°50'N; 97°46'W) in 1 m of water over an oyster-shell bottom. Thirty-two *Mysidopsis almyra* Bowman were found here. Collections were made at two locations on the western shore of Laguna de Tamiahua, Veracruz, a lagoon situated between Tampico and Tuxpan. Ninety-two *M. Almyra* and 16 *M. bahia* Molenock were taken 3 km north of San Geronimo (21°33'30"N; 97°36'30"W) in a natural oil seep area. The water depth was 1.5 m and the bottom consisted of shell mixed with nodules of tar-shell conglomerate. Six km north of this site, 155 *M. bahia* were collected in thick *Ruppia maritima* beds at the confluence of Estero Cucharas River and the lagoon in Cucharas. The water depth was 1.0 to 1.5 m and the bottom was muddy. Four specimens of *Bowmaniella brasiliensis* Bacescu were collected 3 km north of the jetty at Tuxpan, Veracruz (21°00'N; 97°21'W) at the seaside beach in 1 m of water over a sand-shell bottom. Table 1 shows the water temperature and salinity at each location.

The previously known geographic ranges of *M. almyra* and *M. bahia* extended from the southwestern Everglades, Florida (Bowman 1964; Brattegard 1969, 1970; Odum and Heald 1972) to Baffin Bay, an embayment connecting with

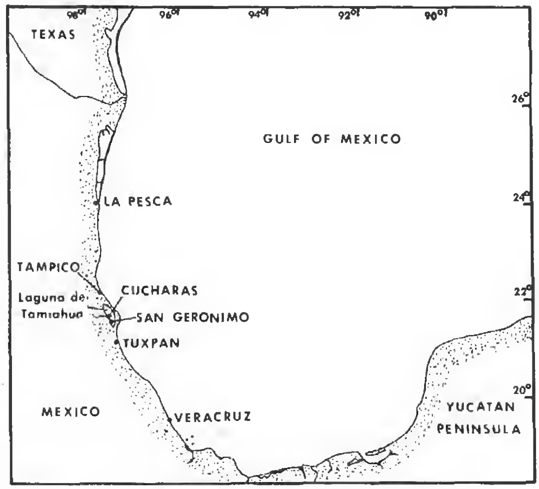

Figure 1. Location of collecting sites on eastern coast of Mexico.

the Laguna Madre on the southern Texas coast (Mackin 1971). This report extends the southern range of these two species approximately 650 km. *Bowmaniella brasiliensis* was previously reported from Brazil, Georgia, the Caribbean coast of Panama (Brattegard 1974), the Galveston Bay area, Texas (Conte and Parker 1971; Price 1976) and Baffin Bay, Texas (Mackin 1971). The collection locality of *B. brasiliensis* reported by this study lies between the previously known locations of Baffin Bay, Texas and the Caribbean coast of Panama; this is in all likelihood indicative of a continuous distribution of this species along the coastal areas of the western Gulf of Mexico and Caribbean Sea.

The developmental groups for the three mysid species at the four locations are shown in Table 1. For *M. almyra* and *M. bahia*, brooding females comprised the largest portion of the population at each location, and mature individuals greatly outnumbered immatures. Females outnumbered males at each site, attaining ratios of 3.4:1.0 for *M.almyra* at San Geronimo and 2.5:1.0 for *M. bahia* at Cucharas.

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Table 1.

Number per developmental group for *M. almyra*, *M. bahia* and *B. brasiliensis* at each location.

Developmental groups	La Pesca (30^a, 14^b)	San Geronimo (31^a, 20^b)		Cucharas (34^a, 18^b)	Tuxpan (25^a, 37^b)
	M. almyra	*M. almyra*	*M. bahia*	*M. bahia*	*B. brasiliensis*
Brooding ♀♀	11	44	5	87	
Broodless mature ♀♀	7	18	1	10	
Mature ♂♂	7	15	7	37	4
Immature ♀♀	4	9	3	14	
Immature ♂♂	3	6	0	7	
Total	32	92	16	155	4

[a]Water temperature °C

[b]Salinity ppt

Length measurements (base of eyestalk to posterior ends of uropods, excluding setae) for collections of *M. almyra* and *M. bahia* from San Geronimo and Cucharas revealed that females were larger than males for both species. Lengths of brooding *M. almyra* averaged 5.6 mm (range 5.0 to 6.7 mm) and mature males averaged 4.9 mm (4.0 to 5.5 mm). The mean length of brooding *M. bahia* was 5.3 mm (4.0 to 6.6 mm) and the mean length of mature males was 4.4 mm (3.8 to 5.4 mm). In Galveston Bay, Texas during May–June 1971/72 and 1973/74, the mean length of brooding *M. almyra* was 4.9 mm (4.3 to 6.8 mm) and the mean length of gravid *M. bahia* was 5.3 mm (4.3 to 6.3 mm) (Price 1976). The average length of the four mature male specimens of *B. brasiliensis* was 6.5 mm (6.3 to 6.7 mm).

Brood size measurements for the San Geronimo and Cucharas collections indicated that brood size increased with increasing length of the female for *M. almyra* and *M. bahia*. Mean brood size was 9.0 young (4.0 to 15.0) for *M. almyra* and 5.5 young (3.0 to 12.0) for *M. bahia*. A similar relationship between brood size and length of female was found for these two species in Galveston Bay, Texas during May–June 1971/72 and 1973/74. However, the mean brood size was 5.4 young (3.0 to 10.0) for *M. almyra* and 7.0 young (3.0 to 14.0) for *M. bahia* (Price 1976).

Several differences exist between the specimens of *M. almyra* described by both Bowman (1964) and Brattegard (1969) and those from the present study. Bowman and Brattegard, respectively, reported 6–7 and 6–8 pairs of long slender spines on the telson apex; my adult specimens had 4–5 pairs of spines. Antennal scales as well as the first and fourth male pleopods of specimens examined during this study agreed with Brattegard rather than Bowman. I found no distal segment on the antennal scale reported by Bowman. In addition adult males had five setae on the pseudobranchial lobes at the base of the endopods of the first and fourth pleopods rather than six as reported by Bowman; in contrast to Bowman's specimens the narrow lobe distal to the pseudobranchial lobe of the fourth male pleopod was lacking. Other characteristics agreed with previous descriptions.

Specimens of *M. bahia* from Mexico agreed with those described by Molenock (1969) and Brattegard (1970) except for two characteristics. Molenock and Brattegard, respectively, reported 4–5 and 4–6 pairs of long slender spines on the telson apex; my adult specimens had 3–5 (usually 4) pairs of spines. The curvature of the anterior dorsal margin of the carapace of my specimens was in agreement with Molenock's illustration which showed it to be broadly triangular and slightly produced between the eyestalks. The anterior carapace margin of Brattegard's specimens was broadly rounded and not produced between the eyestalks.

Several differences were noted between the specimens of *B. brasiliensis* described by Bacescu (1968) and my specimens. Bacescu reported 6–7 lateral spines on the telson and I found 7–8 spines. The cleft depth/telson length ratio from Bacescu's illustration was 0.08 as opposed to 0.12 in this study. The lateral lobes of the sinus and the posterior dorsal margin of the carapace of my specimens were more triangular than the oval-shaped lobes of Bacescu's specimens. The corneal portion of the eye in my specimens was more oblique than the cornea in Bacescu's specimens. Other characteristics agreed with the original description.

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I wish to express my appreciation to the government of Mexico in permitting this study and to Dr. N. E. Strenth for critically reading the manuscript.

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Procedures for Eradication of Hydrozoan Pests in Closed-System Mysid Culture

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PROCEDURES FOR ERADICATION OF HYDROZOAN PESTS IN CLOSED-SYSTEM MYSID CULTURE

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ABSTRACT An unidentified species of hydrozoan in the family Eirenidae was inadvertently transported to the Laboratory with a stock of *Mysidopsis bahia.* The hydrozoan competed for food, ate the young mysids, and subsequently reproduced extensively. Hermit crabs provided minimal control. A detailed transfer procedure for the mysids eliminated the hydrozoans from cultures; hydrozoans were eradicated from tanks after removal of mysids by using 1:1200 formalin, hot water, and Clorox.

In early 1978, a culture stock of *Mysidopsis bahia* Molenock was obtained from the Environmental Protection Agency (EPA) Environmental Research Laboratory at Gulf Breeze, Florida, in order to initiate inhouse stocks for toxicity tests. The mysids were placed into six 10-gallon all-glass aquaria with undergravel filters, a crushed oyster shell substrate, and a salinity of 20–22 ppt (Instant Ocean). They were fed *Artemia salina* Leach larvae twice daily.

No problems in rearing occurred for about 2 months. However, during that time a slight brownish growth on the oyster shell in the tanks had become a dense mat, *Artemia* quickly disappeared, and the mysid populations were decreasing. Examination of the growth revealed hydrozoans containing *Artemia* and young mysids, both polyps and medusae were present.

Some problems with hydrozoans had occurred previously where our stocks were obtained, and hermit crabs were deployed to all tanks to consume the hydrozoans. Specimens of *Pagurus* sp. and *Clibanarius vittatus* (Bosc) were introduced into all our tanks, eight to ten of the former and two to four of the latter per tank. The crabs ate the hydrozoans from the bottom outside edges of all tanks, but not in the center or on the vertical glass sides. The mysid populations continued to decrease; the hydrozoans both competed for *Artemia* as food and preyed on young mysids.

In early May 1978, samples of the hydrozoan were sent to Dr. D. R. Calder. Calder (personal communication) replied that "the specimens belong to the family Eirenidae, which now also encompass the old family Eutimidae, . . . The hydroids of this family are very poorly known, as are the juvenile medusa stages. In fact it is likely that this hydroid is undescribed."

From 26 May to 1 June 1978 formalin (Sandifer et al. 1974) was used in the tanks (two tanks treated every other day), according to our procedures, to control the hydrozoan pest. During the following 5 months there was no recurrence of the pest, and it was considered to be successfully eradicated.

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PROCEDURES

Procedures developed during this study are presented in a step-by-step order for ease in following.

Mysid Handling

1. Set up one or more 10-gallon all-glass aquaria (isolation tanks) with an air stone, no oyster shell, a filter, and the same salinity as the mysid tanks.
2. Filter overnight, then switch to air stone. Introduce four to six hermit crabs whose shells have been scrubbed to remove hydrozoans.
3. Use a small-mesh dip net to collect mysids out of hydrozoan-infested tanks and put them into clean tank with air stone and hermit crabs (to eat transferred hydrozoans). Feed mysids brine shrimp. Leave mysids in tank at least 2 days.
4. Follow procedures for eradication (see Hydrozoan Eradication section).
5. Net mysids (20 to 30 at a time so pan is not crowded with mysids and debris) out of isolation tank and put into white procelain sorting pan.
6. Sort out all hydrozoans observed in pan and discard.
7. Then, using a small net (1 cm sq, small mesh) or eye dropper, isolate and transfer each mysid individually to a small finger bowl. Remove any hydrozoans observed in bowl.
8. Put mysids in finger bowl back into cleaned original tanks; feed brine shrimp.
9. Do not put hermit crabs back into cleaned tanks as they may have hydrozoans attached to their shells.

Hydrozoan Eradication

1. After mysids are removed, add 30 ml formalin per 10-gallon tank (concentration = about 1:1200, due to volume of shell and filter parts). Let stand at least 2 hours.
2. Siphon off water and discard.
3. Remove shell and scald thoroughly with hot water in a bucket, or discard shell.
4. Rinse and scrub tank thoroughly with fresh water.
5. Fill tank with fresh water and add 2–4 tablespoons of Clorox; put all filter parts into tank. Let stand at least 1 hour.

6. Rinse and scrub tank and filter parts with fresh water. Flush tank and filter parts, and shell in bucket, with flowing fresh water for at least 2 to 3 hours.
7. Set up cleaned tank with sea water and filter overnight.

Nine days after the above procedures two of six tanks of mysids were lost, presumably due to residual formalin still in the oyster shell substrate or on the glass tank walls or filters. The remaining four tanks were disassembled, thoroughly scrubbed (four–five times), and rinsed with fresh water for 5 to 6 hours each; the shell was discarded. Tanks were set up with new shell; no further related die-offs have occurred. Thus, we recommend that the substrate be discarded and the tanks and all filter parts be thoroughly scrubbed and rinsed prior to re-introduction of mysids.

Over three times the concentration of formalin suggested by Sandifer et al. (1974) was used due to the lack of response by the brine shrimp in the tanks to the formalin. They added 250 ppm (1:4000); we added formalin in 10 ml doses three times (about 1:1200) before a majority of the brine shrimp were affected (swimming ceased).

Polychaetes that reside in the shells were added to mysid tanks along with hermit crabs. Although the effects of polychaetes on mysid cultures are presently unknown, polychaetes did not appear to cause any harm in the tanks.

Procedures similar to those presented here may be used in eradicating hydrozoan pests in closed-system culture of other invertebrates.

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Dr. D. R. Nimmo of the EPA Environmental Research Laboratory at Gulf Breeze, Florida, kindly provided us with our stock of *Mysidopsis bahia*. Dr. D. R. Calder of the Marine Resources Research Institute, Charleston, South Carolina, provided information on the hydrozoan.

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Geographical Definition of Mississippi Sound

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GEOGRAPHICAL DEFINITION OF MISSISSIPPI SOUND

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ABSTRACT Boundaries for Mississippi Sound are determined by application of definitions, established surveying practices and observations of the physical processes of the area. U.S. Coast and Geodetic charts 1266 (1972 edition), 1267 (1972 edition) and 1268 (1974 edition) were used in ascertaining the boundaries. These boundaries provide a formal geographical definition for Mississippi Sound.

The geographical boundaries of Mississippi Sound are ill-defined by natural features especially at the western end. This lack of generally recognized boundaries is a cause of confusion among individuals and agencies with an interest in this water body. Because of this vagueness, it is presently necessary to provide a chart or clear description of the area one refers to as "Mississippi Sound."

Of the several definitions of a sound (Gary et al. 1972), two seem appropriate for Mississippi Sound; (1) "An arm of the sea forming a channel between a mainland and an island"; (2) "A long, large, rather broad inlet of the ocean, generally extending parallel to the coast." Mississippi Sound (Figure 1) is an elongated basin with its major axis parallel to the Gulf of Mexico from which it is partly separated by a series of barrier islands.

U.S. Coast and Geodetic charts 1266 (1972 edition), 1267 (1972 edition), and 1268 (1974 edition) were used in determining the boundaries of Mississippi Sound. The line segments shown are what the author proposes to be boundaries that are justifiable by definitions, accepted surveying practices and observations of the physical processes within the basin.

The problem of defining the specific limits between two bodies of water is not always a simple one. The solution lies in finding the exact place where the water bodies merge. The "headland-to-headland" principle (Shalowitz 1964) has been deduced based on consideration of the physical configuration of the water bodies. This principle considers the boundary between a tributary water body and a larger water body to be a line joining the headlands of the tributary water body. The headland rule has been applied in various contexts to bays and rivers.

Two rules (Shalowitz 1964) have been established in the case of determining boundaries where rivers flow directly into a water body. Cognizance has been taken internationally of the headland-to-headland principle at the 1930 Hague Conference for the Codification of International Law. The proviso contained in the final report of the Second Sub-Committee of the conference states that "when a river flows directly into the sea, the waters of the river constitute inland waters up to a line following the general direction of the coast drawn across the mouth of the river, whatever its width." The second rule provides that "if a river flows directly into the sea, the baseline shall be a straight line across the mouth of the river between points on the low-tide line of its banks." This rule is a recommendation of the International Law Commission in its final report to the United Nations, as is Article 13 of the 1958 Convention on the Territorial Sea and the Contiguous Zone. The recommendation of the International Law Commission is the convention

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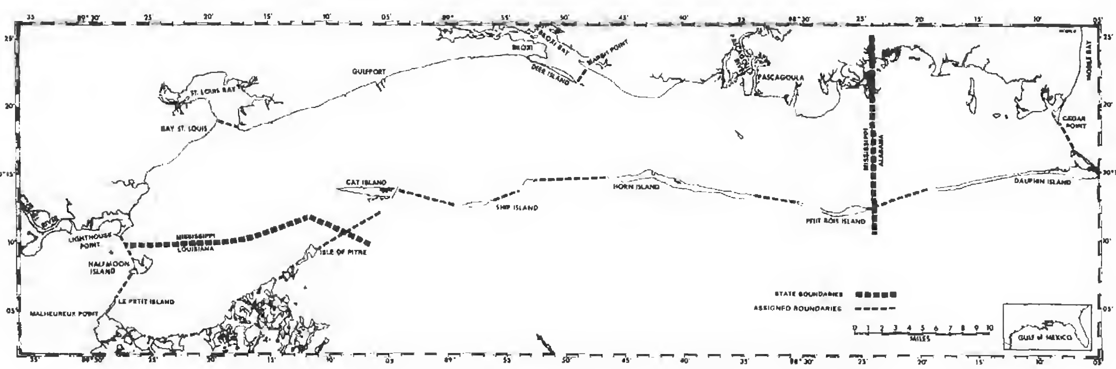

Figure 1. Mississippi Sound showing location of State and natural boundaries.

that was applied here in determining the boundaries between rivers and Mississippi Sound.

A "bay" according to Geneva Convention (Shalowitz 1964) is "a well-marked indentation whose penetration is in such proportion to the width of its mouth as to contain landlocked waters and constitutes more than a mere curvature of the coast. The area of such an indentation must be as large as, or larger than the semicircle whose diameter is a line drawn across the mouth of the indentation." This definition was applied to Mississippi Sound in distinguishing between true bays and those areas erroneously named bays.

The Sound's eastern boundary with Mobile Bay is defined by a line connecting the narrowest point between the Alabama mainland and Dauphin Island. The same convention would be used in determining the boundary between the barrier islands of Dauphin, Petit Bois, Horn, Ship and Cat.

The boundary from Cat Island extends from the south end of the south spit to the Isle Au Pitre. This particular boundary, while somewhat arbitrary, was decided on for two reasons. First, the south spit of Cat Island which continues south-southwest as a submarine topographic feature serves as a line of demarcation with the Gulf of Mexico. Second, the area south of Cat Island Pass is probably more properly labeled a tongue of the Gulf than an extension of Chandeleur Sound and therefore this boundary appears more appropriate than any alternative.

The western boundary of Mississippi Sound is best defined by lines connecting Malheureux Point with Le Petit Island, Le Petit Island with Half Moon Island and Half Moon Island with Light House Point. Malheureux Point was connected with Le Petit Island across the narrowest point of Le Petit Pass. Le Petit Island and Light House Point were connected in a similar manner with Half Moon Island. These boundaries clearly separate Mississippi Sound from Lake Borgne.

The boundary with St. Louis Bay is across the bay entrance at its narrowest point. The west entrance to Biloxi Bay is denoted by a line projected north to the mainland from the west tip of Deer Island. The Mississippi Sound/Biloxi Bay boundary at the east bay entrance is a line connecting the easternmost tip of Deer Island with the mainland at the nearest point. There were two reasons for not projecting this boundary from Little Deer Island: (1) Sound waters pass freely between it and Deer Island; and (2) it is rapidly disappearing (personal observation) and will not long be available for boundary determination. A line projected across the mouths of Pascagoula River completes the assigned boundaries of Mississippi Sound.

Bays such as Pascagoula, Point Aux Chenes, Grand, Portersville and Heron are not considered separate and distinct water bodies, i.e., true bays, but integral parts of Mississippi Sound. This decision is based on the failure of the areas to qualify as "bays" under the definition of "bay" according to Geneva Convention.

This determination of boundaries provides for the formal geographical definition of Mississippi Sound. The coordinates of latitude and longitude for the assigned boundary lines appear in Table 1. These boundaries are practical in that they are easily remembered and almost as easily located at sea. It is hoped that this geographical definition in clarifying what constitutes "Mississippi Sound" will help end the present confusion.

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I wish to thank Mrs. Joyce Edwards for her interest in the work and efficiency in handling the typescript.

TABLE 1.

Latitude (N) and longitude (W) of ends of assigned boundaries from east to west.

From	To	From		To	
Cedar Point, AL	Dauphin Island, AL	30° 17.1′	88° 7.5′	30° 18.6′	88° 8.2′
Dauphin Island	Petit Bois Island, MS	30° 13.9′	88° 19.3′	30° 12.3′	88° 24.4′
Petit Bois Island	Horn Island	30° 12.8′	88° 30.4′	30° 13.3′	88° 33.9′
Horn Island	Ship Island	30° 14.6′	88° 46.5′	30° 14.6′	88° 52.3′
Ship Island Cut (Camille Cut)		30° 13.8′	88° 53.6′	30° 13.0′	88° 56.1′
Ship Island	Cat Island	30° 12.6′	88° 59.2′	30° 14.2′	89° 4.0′
Cat Island	Isle Au Pitre	30° 10.8′	89° 6.8′	30° 9.5′	89° 11.0′
Le Petit Island	Malheureux Point	30° 4.8′	89° 28.6′	30° 5.1′	89° 29.0′
Half Moon Island	Le Petit Island	30° 7.6′	89° 26.6′	30° 5.9′	89° 28.1′
Half Moon Island	Light House Point	30° 8.8′	89° 26.7′	30° 10.4′	89° 27.7′
Narrows of Entrance	St. Louis Bay	30° 18.4′	89° 17.6′	30° 18.6′	89° 19.5′
Deer Island (west)	Biloxi (mainland)	30° 21.1′	88° 53.0′	30° 21.1′	88° 53.1′
Marsh Point (mainland)	Deer Island (east)	30° 20.3′	88° 47.9′	30° 19.2′	88° 48.9′
Creole Gap (LA marsh)		30° 8.5′	89° 12.7′	30° 8.2′	89° 13.2′
Grand Pass (LA marsh)		30° 7.7′	89° 14.0′	30° 7.3′	89° 14.7′
Three-Mile Pass		30° 3.1′	89° 21.4′	30° 2.9′	89° 22.2′
Kennedy Lagoon (LA marsh)		30° 3.0′	89° 25.3′	30° 3.1′	89° 25.8′
Blind Bay (LA marsh)		30° 2.8′	89° 24.5′	30° 3.0′	89° 25.3′

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New Hosts for Lymphocystis

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NEW HOSTS FOR LYMPHOCYSTIS

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ABSTRACT Lymphocystis disease is reported for the first time from the Koran angelfish, *Pomacanthus semicirculatus;* the Moorish idol, *Zanclus canescens;* the foureye butterflyfish, *Chaetodon capistratus;* and the orbiculate bat fish, *Platax orbicularis.* Also, lymphocystis is reported the second time from the queen angelfish, *Holacanthus ciliaris.* All hosts are commercially important exotic aquarium fishes.

INTRODUCTION

Lymphocystis is an infectious viral disease of teleosts that causes hypertrophy of connective tissue cells and usually occurs on the fins and skin. The enlarged cells (nodules) eventually slough off; there is no known treatment, but the disease is seldom fatal. A list of hosts reported to be susceptible to the disease since the work of Nigrelli and Ruggieri (1965) was presented by us previously (Lawler et al. 1977). We add four more species to the host list.

MATERIALS AND METHODS

All the fish examined were imported for sale in tropical fish stores. They were relaxed with MS–222 (Tricaine methanesulfonate, Cresent Research Chemicals Inc., Scottsdale, Arizona) and examined alive, so that they could be returned to display tanks. Suspected lymphocystis tissue was removed with forceps, examined under a compound microscope for confirmation of lymphocystis, and preserved in 10% buffered formalin for future microscopic examination. No internal organs or gills were examined. The fish were revived in fresh sea water of about the same salinity from which they were removed.

Preserved lymphocystis tumors were examined with a Siemens 1A Elmiskop electron microscope following the procedures of Lawler et al. (1974). Approximate diameters of viral particles (diameter = distance between opposite vertexes) are enclosed in parentheses in the discussion of each case report.

CASE REPORTS

1. ***Pomacanthus semicirculatus* (Cuvier and Valenciennes), Koran angelfish; family Chaetodontidae.** The fish occurs from the Red Sea and Indian Ocean to the Indo-Australian Archipelago, the Philippines, China, Okinawa, and Melanesia (Axelrod and Emmens 1969).

On 29 August 1977 two juveniles were examined, both approximately 60 mm long (total length [TL]). One had hypertrophied cells on the right pectoral fin; the other had small nodules on all fins. The fish had been imported from the Philippines through California, and were heavily infected when received. They were held for about 4 weeks prior to microscopic examination, at which time most of the nodules were gone. The course of the disease (287 nm) in this species appears to last at least 4 weeks.

2. ***Zanclus canescens* (Linnaeus), Moorish idol or toby; family Zanclidae.** The fish occurs widely in the tropical Indo-Pacific, from the Red Sea to Mexico (Axelrod and Emmens 1969).

On 15 December 1977 one fish was examined. This fish, already infected, was imported from the Philippines through California on 19 November 1977 and was held in a tank at 32 ppt salinity until examination. The fish (70 mm TL) had clumps of lymphocystis cells on the dorsal fin and at the base of the left pectoral fin. Single nodules were scattered on the skin. It appears, that in this species also, the disease (287 nm) lasts at least 4 weeks.

3. ***Chaetodon capistratus* Linnaeus, foureye butterflyfish; family Chaetodontidae.** The fish occurs in the tropical Atlantic and Caribbean (Axelrod and Emmens 1969).

On 21 December 1977 one fish recently imported from Florida was examined. This fish (51 mm TL) had clumps of lymphocystis cells on the left pectoral fin and single nodules scattered on both the dorsal and caudal fins. On 10 February 1978, four more fish were received; all had lymphocystis (287 nm).

4. ***Platax orbicularis* (Forskäl), orbiculate bat fish; family Platacidae.** The fish occurs widely from the Red Sea, Indian Ocean, and Indo-Australian Archipelago to the Philippines, China, south Japan, and central to south Pacific islands (Axelrod and Emmens 1969).

Three fish were observed infected on 28 January 1978. The fish having the greatest infection (259 nm) died on 19 January 1978 apparently from another cause and was examined microscopically the next day. The fish (64 mm TL) had clumps of lymphocystis cells on the caudal, dorsal, anal, right pectoral, and both pelvic fins; scattered lymphocystis cells occurred on the skin.

5. ***Holacantus ciliaris* (Linnaeus), queen angelfish; family Chaetodontidae.** The fish occurs from the Bahamas to Brazil, including the Gulf of Mexico (Böhlke and Chaplin 1968).

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A queen angelfish (210 mm TL) received from Florida was examined on 10 February 1978. It had lymphocystis nodules on the dorsal, anal, and pectoral fins; the infection later spread to the skin underlying the pectorals. The fish died on 3 April 1978, still showing numerous nodules. The course of the disease (287 nm) in this fish was greater than 2 months. This is the second report of lymphocystis on this species, the first being Nigrelli and Ruggieri (1965).

6. ***Zebrasoma veliferum*** **(Bloch), sailfin tang; family Acanthuridae.** The fish occurs in the tropical Indo-Pacific and Red Sea (Axelrod and Emmens 1969).

On several occasions apparent lymphocystis nodules have been observed on fish of this species being held in display tanks. However, at present, lymphocystis has not been confirmed microscopically.

DISCUSSION

With increased new findings of infected hosts among imported fishes, we agree with McCosker et al. (1976) who noted that "it is quite likely that many infected species remain unreported, particularly among families of tropical reef fishes." Although fish that were already infected, or soon showed signs of infection have been received, it has not been ascertained whether there is more than one strain of lymphocystis in these tropical fishes. Lawler et al. (1974) have already noted viral strain differences occurring in the Gulf of Mexico between two closely related hosts, *Bairdiella chrysura* (Lacépède) and *Micropogonias undulatus* (Linnaeus).

Although one may think that most aquarium fish are subject to lymphocystis infections, this is not so. Confinement in aquaria can lead to an increased prevalence of lymphocystis in specific hosts so maintained, but out of about 40,000 to 50,000 described species only about 100 (Lawler et al. 1977), or about 0.2%, have ever been reported with lymphocystis.

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CLASSIFICATION OF MISSISSIPPI SOUND AS TO ESTUARY HYDROLOGICAL TYPE

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ABSTRACT Mississippi Sound is classified as to estuary hydrological type by the method of Pritchard (1955). Differences in salinity between surface and near-bottom water were calculated from 2,401 pairs of observations made at 90 stations from 4 April 1973 to 12 April 1977. Frequency distribution tables, constructed by tallying the vertical salinity differences into three classes corresponding to three of Pritchard's estuary types (A, stratified; B, partially mixed; D, well mixed) were used to assess salinity structure of the water column. The greatest variation as to type occurred from January through June. From July through December, the water column becomes predominately uniform. Mississippi Sound is shown to be primarily well mixed with approximately one-third of the observations indicating partially mixed and less than 2% being stratified. The channels are characteristically stratified or partially mixed. The results of this study were in good agreement with the previous classification by another method by the author which confirms that while dominately well mixed, Mississippi Sound also attains the characteristics of a partially mixed estuary and, highly localized, characteristics of a stratified estuary.

INTRODUCTION

The classification of an estuary as to hydrological type, essential to understanding the estuarine physical-chemical-biological processes, is determined according to circulation patterns and salinity distribution. The difference between hydrological types is related to variations in width, depth, tidal range and volume of river flow.

Located on the northern Gulf of Mexico, Mississippi Sound (Figure 1) is an elongate estuarine basin with a surface area of 2,128.87 km^2 and average depth at mean low water (MLW) of 2.98 m (Higgins and Eleuterius 1978) that connects with the Gulf through passes between a series of five barrier islands. The estuary receives an influx of fresh water via two major rivers, Pascagoula and Pearl; four minor rivers, Biloxi, Tchouticabouffa, Jourdan and Wolf; and a number of bayous. River discharges in cubic meters per second for the six rivers are: Pascagoula, 378.35 m^3; Pearl, 327.72 m^3; Biloxi, 13.97 m^3; Tchouticabouffa, 12.36 m^3; Jourdan, 23.47 m^3; and Wolf, 19.98 m^3. Sound tides are diurnal with an average range of 0.57 m. Two ship channels cross Mississippi Sound, Gulfport channel with a project depth of 9.1 m and Pascagoula channel with a project depth of 11.6 m, which permit the intrusion of high-salinity Gulf waters.

Eleuterius (1978) determined on the basis of the ratio of surface-to-bottom salinity that Mississippi Sound fluctuates between a well-mixed and partially mixed estuary. From January through June, Mississippi Sound showed a diversity of types while the July through December period was shown to be predominately well mixed. A review of the literature revealed no other attempts at hydrologic classification of Mississippi Sound.

Pritchard (1955) developed a classification system with four estuarine types: Type A, two-layered or stratified; Type B, partially mixed; Type C, laterally homogeneous; and Type D, vertically homogeneous or well mixed.

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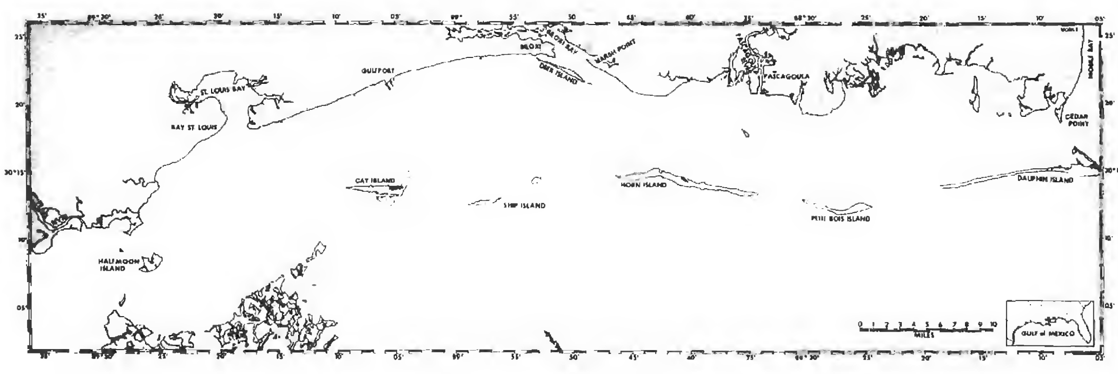

Figure 1. Mississippi Sound.

Because Eleuterius (1976) showed that Mississippi Sound's complex circulation precluded its being a Type C (laterally homogeneous) estuary, this type was not considered in this investigation. Evidence is presented here to indicate the classification of the Sound employing the system of Pritchard (1955).

MATERIALS AND METHODS

Salinity data were collected during a hydrographic investigation of Mississippi Sound from 4 April 1973 through 12 April 1977. Sampling was conducted approximately biweekly for a period of at least a year at each of 90 stations (Figure 2). Salinity measurements were made within the upper 30 cm of the water column and within 60 cm from the bottom. Conductivity readings that were later converted to salinity were made with a Martek Model II with an accuracy of ±0.2 mmho/cm (±0.5 parts per thousand [ppt] salinity).

Stations were sorted according to water depth at MLW as shown on U.S. Coast and Geodetic Charts 1266 (1972 edition), 1267 (1972 edition) and 1268 (1974 edition) into four classes: ≤ 1.5 m; > 1.5 m but < 3.0 m; > 3.0 m but ≤ 4.5 m; > 4.5 m. Stations in the fourth class were further separated into two groups: those stations located in either the Pascagoula or Gulfport ship channels; those located outside of the channels. The differences in salinity between surface and near-bottom waters were then determined for all depth-classes on a total of 2,401 pairs of observations. The resulting differences for each depth-class were tallied into monthly frequency distribution tables. The tables consisted of three frequency classes: differences ≥ 20.0 ppt, Type A; ≥ 4.0 ppt but < 20.0 ppt, Type B; < 4.0 ppt, Type D. Inspection of the data revealed no pronounced trend differences between depths except for the channel stations; therefore, two composite frequency tables were constructed, one which included data from all stations and the other limited to data from outside the ship channels.

RESULTS AND DISCUSSION

Table 1 shows that the greatest variability in estuarine type occurs from January through June, corresponding to the high river flow of winter and spring. However, 65.2% of the paired observations taken during March indicated the water column to be well mixed, apparently the result of strong winds usually experienced during this month. Only 1.3% of the March surface-to-bottom salinity differences could class the water column as stratified. With the exception of January, more than 50% of the paired observations for each month were in the well-mixed class. In January, 9% of the observations showed stratification while the remaining observations were equally divided between partially mixed and well mixed.

A sharp change in the water column in July is apparent with 73.0% of the difference in the well-mixed category.

TABLE 1.

Distribution according to estuary type of observations of surface-bottom salinity differences (percent) from 90 stations in Mississippi Sound.

Month	Number of Paired Observations	Stratified	Partially Mixed	Well Mixed
January	143	9.0	45.5	45.5
February	265	2.7	42.6	54.7
March	164	1.3	33.5	65.2
April	214	2.3	44.9	52.8
May	248	3.3	42.3	54.4
June	276	1.5	43.1	55.4
July	274	1.1	25.9	73.0
August	186	0.0	11.8	88.2
September	165	0.0	30.3	69.7
October	121	1.7	7.4	90.9
November	169	0.6	13.6	85.8
December	176	1.1	30.1	68.8
Average		2.05	30.92	67.03

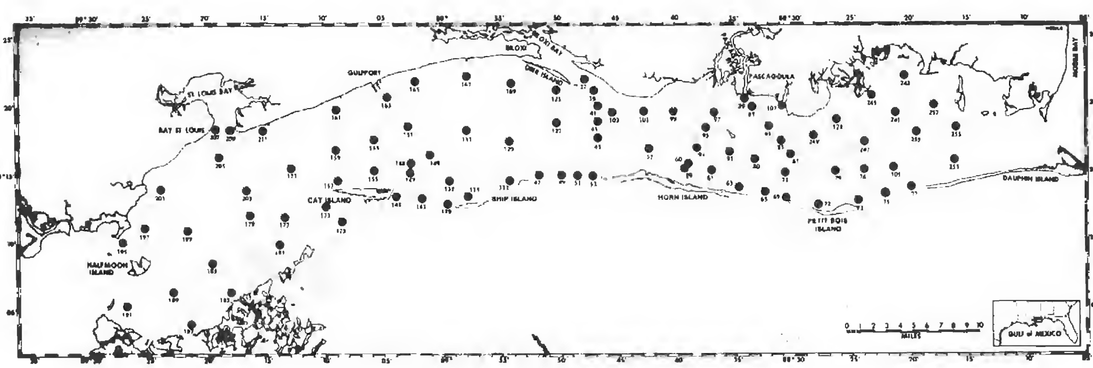

Figure 2. Station locations in Mississippi Sound.

This trend toward vertical homogeneity reaches a peak in October when 90.9% of the differences show a well-mixed system. River flow is at its low during October. The water column, while still dominately well mixed, becomes more varied during November and December. Averaging the monthly percentages showed the following: 2.0%, stratified; 31.0%, partially mixed; 67.0%, well mixed.

To evaluate the influence of stations located in the ship channels on the classification of Mississippi Sound, a second table, Table 2, was constructed using only salinity observations from stations located outside of the Pascagoula and Gulfport ship channels. The general trend is the same as when the channel stations were included; however, there are notably smaller percentages in the stratified and partially mixed classes. The abrupt increase in the well-mixed class for the July–December period is primarily due to a shift from the partially mixed class. The month showing the greatest uniformity of the water column was again October with 94.6% of the salinity differences less than 4.0 ppt. The averaged monthly percentages in each class show less than 1%, stratified; 26.95%, partially mixed; 71.87%, well mixed.

TABLE 2.

Distribution according to estuary type of observations of surface-bottom salinity differences (percent) from 78 stations in Mississippi Sound outside of ship channels.

Month	Number of Paired Observations	Stratified	Partially Mixed	Well Mixed
January	132	5.4	42.4	49.2
February	233	0.9	38.2	60.9
March	149	0.7	29.5	69.8
April	192	0.5	41.2	58.3
May	221	0.5	39.8	59.7
June	242	0.4	37.2	62.4
July	241	0.5	18.8	80.7
August	170	0.0	10.0	90.0
September	149	0.0	25.5	74.5
October	111	0.9	4.5	94.6
November	153	0.7	11.1	88.2
December	155	1.3	25.2	73.5
Average		0.98	26.95	71.87

According to the classification of Pritchard (1955), Mississippi Sound varies between types A, B and D but is predominately Type D (well mixed). The period when the water column shows the greatest variability is from January through June — the time of increased river flow. In July, Mississippi Sound becomes notably more homogeneous. This period of tendency to vertical homogeneity, peaking in October, lasts through December. When the channel areas are excluded from the classification procedure, the average of the monthly percentages indicating a stratified system is less than 1% while that for a well-mixed system is approximately 72%. The channels are characteristically stratified or partially mixed. The results of this study were in good agreement with the previous classification by the author (Eleuterius 1978) which confirms that while dominately well mixed, Mississippi Sound also attains the characteristics of a partially mixed estuary and, highly localized, characteristics of a stratified estuary.

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